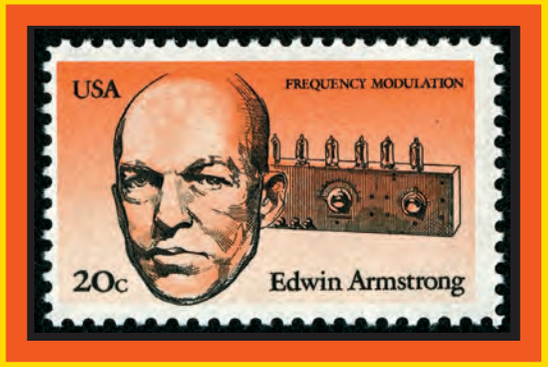

34

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Cover Images: The front cover shows a tower at Alpine, NJ, that E. H. Armstrong used in tests of the frequency modulation system of radio. The corner of the building is the W2XMN transmitter building. The back cover shows USPS Scott #2056 stamp, honoring Edwin Howard Armstrong, the inventor of frequency modulation. Armstrong laid the foundation for much of modern radio and electronic circuitry, including the regenerative and superheterodyne circuits. Front cover image courtesy of Columbia University Library Armstrong Archive. Back cover image courtesy of United States Postal Service.

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Foreword

Once again we are fortunate to have many interesting, well-written and well-researched articles recounting various events, adventures, people, companies, inventions, and milestones in the history of electronic communication. Below is a brief summary of each of the articles in the order that they appear.

- **Chuck Penson** presents a history of electronic kits in the United States. Heath was the largest and most successful purveyor of kits in the history of electronics. However there were many other players, before, during, and after Heath. His paper presents a brief history of electronic kits chronologically with many important milestones noted for reference. Perhaps we can all reminisce about our early days when we built kits.

- **Donna Halper** presents an historical account about the important role that amateur radio operators played in early commercial broadcasting. This was partly because the amateurs knew how to build their own radio sets, which was an essential skill in that era before radio receivers were mass-produced and available in department stores. Amateurs were also the ones who told their family and friends about radio. Thus, it makes sense for the amateurs to be included in the history of broadcasting, especially since the development of commercial radio is often told as the story of a new technology. The inventors and engineers working for innovative companies designed, manufactured, and subsequently improved upon the apparatus that made broadcasting possible.

- **John Okolowicz** tells us about the phenomena of industrial design and the design of things manufactured on an assembly line as applied to radios. Prior to the design era was the era of handcrafted items designed and created by individual artisans. Early mass-produced radios tended to be crude and visually gaudy, but most consumers didn't mind because it was the latest technology. In fact, they were delighted that this high-tech equipment was available at reasonable prices and offered benefits that never existed before. This was soon followed by artistic and attractive case and cabinet designs suitable for use in the living spaces.

- **David and Julia Bart** have written an article to mark the 160th anniversary of the 1861 completion of the transcontinental telegraph in the United States. The authors explore the strategic wars that were fought over this new electric communication line. Both the Mormon and Native American experiences reflect positive and even enthusiastic support for building the transcontinental telegraph; he explains how their views diverged as the new technology spurred further

settlement, which was used to help secure the frontier. These wars, previously thought to be somewhat randomly executed, reflected specific strategic choices applied over a wide-ranging, harsh environment where brutal methods of warfare became the norm. Critically, they reflect a keen awareness by contemporary players about the importance of the transcontinental telegraph and its implications for controlling America's western territories.

- **Mike Molnar** describes the development of the FM system of radio as spearheaded by its inventor, Edwin Howard Armstrong. The FM system was shown to have some advantages over the AM system. Armstrong fought many long legal battles with big companies and their lawsuits, as the AM system was already established and many saw FM as a competitor. The fight was enough to drive anyone to lose control of their right mind. Molnar also describes the circuit workings of early FM radio receivers and FM convertors that were built.

- **Michael Marinaro** presents a rendition of the circumstances, events, and radio stations that brought the phenomena of wireless communications to World War I, or The Great War as it was called then. The genius of the Italian inventor Guglielmo Marconi was to be challenged with the need for ever-increased communications range as the world was on the verge of a series of wars, which were the prelude to the big one: The War to End All Wars. These smaller wars were the first in which innovative weapons such as wireless were utilized. In an addendum, a story is told about the American communications expert Allesandro Fabbri and the radio station he established at Otter Cliffs, Maine, upon the United States involvement in World War I.

- **Eric Wenaas** gives an account of the wireless experiments of Sir Oliver Lodge. Lodge established a remarkable reputation during the last decade of the 19th century when the scientific community credited him with the development of several primary inventions that are the basis of radiotelegraphy. Historians of the 20th century were kind to Lodge in their accounts of his work. It has become increasingly clear in publications in the last 20 years that Lodge claimed credit for more than he actually accomplished in the last two decades of the 19th century. There have been assertions that Lodge rewrote the history of his major accomplishments, most notably in his autobiography. Indeed, convincing evidence has been published to support the contention that he did not discover the coherer principle or invent radiotelegraphy by being the first to transmit telegraphic messages using Hertzian waves. There is also ample evidence that Lodge knowingly altered the details of his experiments to support his false claims.

We thank all of our authors for sharing their work with us. I personally thank each one of them for the cordial interactions we have had while preparing the manuscripts. I also want to thank our associate editor, Eric Wenaas, and our peer reviewers who have worked so hard and given so much time to review and edit these papers. Finally, I would like to thank Fiona Raven for the wonderful article layouts that we have come to expect each year—and especially for the original layouts on the covers of the *AWA Review*. Fiona's professional and creative work never ceases to amaze, and she makes all our authors look great.

Several years ago, the AWA created the Robert P. Murray Award in honor of Robert Murray, long-time *AWA Review* editor, and now Editor Emeritus, for excellence in writing in the *AWA Review*. The third award was presented virtually at the AWA Conference in Rochester in 2020 to David and Julia Bart. Congratulations to David and Julia for a job well done; we know they will continue to write high quality articles in the future.

This is my second year as editor. I have greatly enjoyed this assignment and look forward to editing future editions. I hope my effort meets or exceeds the quality you have come to expect. My professional background as a systems engineer in major high-tech companies developing military weapons systems has well prepared me to pay attention to the detail needed and to meet the workload and scheduling requirements. My life-long amateur radio hobby and interest in all things electronic has provided a deep and yet broad background in radio communications and electronics of all kinds.

Tim Martin, WB2VVQ
Editor, *AWA Review*
Lee, MA

Tips for Authors

The *AWA Review* invites previously unpublished papers on electronic communication history and associated artifacts, with a focus on antique wireless. Papers will be peer reviewed to verify factual content by peer reviewers whose identity will remain anonymous. This process gives the *AWA Review* credibility as a source of correct historical information. The papers will be edited to provide uniformity in style and layout among the articles. In general, shorter articles of six to eight pages (3,000 to 4,000 words) or less should be directed toward the *AWA Journal*, which is published quarterly. The *AWA Review* is intended for longer articles on the order of 6,000–9,000 words. Longer articles may be accepted with pre-approval by the editor, or then may be split into several parts.

The *AWA Review* will also publish Letters to the Editor as deemed appropriate. Letters should comment on articles published in the previous issue of the *AWA Review* or make brief comments on wireless history as it relates to one of the articles. Letters will not be peer reviewed, but they may be edited. Text is limited to 400 words and no more than 10 references. The editor reserves the right to publish responses to letters.

It is strongly recommended that authors planning to prepare an article for the *AWA Review* send an abstract of approximately 200 words to the editor describing the subject and scope of the paper before writing the article, including an estimate of the number of words. It is never too early to submit an abstract. Space in the *AWA Review* is not unlimited, so it is important for both editors and authors alike to have an estimate of the expected number of articles and number of pages for each article as soon as possible. The deadline for submissions of manuscripts in the next issue is January 1, 2022. Papers will be accepted after January 1, but papers submitted and accepted for publication before January 1 will have priority in the event that there is not space for all papers submitted.

Authors with an interesting story to tell should not be discouraged by a lack of writing experience or lack of knowledge about writing styles. The *AWA Review* will accept manuscripts in any clearly prepared writing style. Editors will help inexperienced authors with paper organization, writing style, reference citations, and improvements in image quality. Edited manuscripts will be returned to the author along with comments from the editor and anonymous reviewers for the author's review and comment. The manuscript will then be set in its final form and sent back for one final review by the author. Normally, only one review of the layout will be accommodated.

To summarize, please submit completed manuscripts by January 1, 2022 (or earlier if possible) in three separate files:

1) A manuscript file without embedded figures or figure captions using Microsoft Word or other software that is compatible with Word. The manuscript should have a 200-word abstract, a main body with endnote citations and endnotes, acknowledgements, and several paragraphs summarizing the author's background. The author should also enclose a recent photograph focusing on the head and shoulders.

2) A figure folder, with one figure per file, with numbered figures and files that match the figure callouts, which must appear in at least one sentence of the manuscript text. Each figure file name should have several words of descriptor related to the image in addition to the figure number.

3) A figure caption file with a description of each figure and an attribution identifying its source. You may use the articles in this issue as a template for the style and format of your paper. For more information, consult the AWA website at http://www.antiquewireless.org/awa-review-submissions.html. Please feel free to contact me as editor for the *AWA Review* for any questions.

Timothy Martin, BE, ME, PE
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A Brief and Incomplete History of Kits: A Heath-Centric perspective

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When you think of electronic kits, it is very likely that you think of Heathkit. This is entirely understandable. Heath was the largest and most successful purveyor of kits in the history of electronics. Of course, Heath did not invent kits. There were other players. Many other players. Still, it is not possible to discuss the history of kits without mentioning Heath, at least parenthetically. This paper presents a brief history of electronic kits, mostly in chronological order, with a few important milestones noted for reference.

Kits in Context

Electronic kits have been around almost since the dawn of radio, and there have been many players, large and small, spanning almost the entirety of the twentieth century. A comprehensive discussion of the history of electronic kits would require a book-length treatise, and it seems like a worthy subject, but I'll save it for others. Most electronics enthusiasts can name a half dozen or so kit makers. There were, in fact, dozens at least, and perhaps hundreds. In this brief study, I will make no attempt to name every kit maker of the 20th century. It is possible here only to scratch the surface of the subject in order to give the reader some context, some historical sense of the depth and breadth of an industry that has been largely obscured by the dominance of a single company.

As a side note, and before delving into the history of kits, it is worth noting that in discussions about Heath's founder, Howard Anthony, it has often been said that he was inspired by the company's namesake, Ed Heath, and his kit airplanes. Perhaps. But a better and more plausible explanation, in my opinion, would be that Anthony was inspired directly by the electronic kits that could be found in every radio and electronics-related magazine of his time.

By 1930, when Anthony was 18 years old, electronic kits had been firmly established in the radio and electronics marketplace. The intellectually curious Anthony may have found the idea of kits to be uniquely captivating. At so young an age, he did not have the means to pursue anything like making and selling kits (at least not on any serious scale), but the idea may have stuck with him after WWII, when he found himself both fabulously wealthy—and surrounded by mountains of war surplus electronics. In such circumstances, it would have been extraordinary for such an enterprising person as Anthony if he had *not* thought about kits. Kits were omnipresent.

The Appeal of Kits

The fondness for assembling an electronic kit is not much different than any other immersive activity. Painting, writing, needlework, wood or metalworking, stamp or coins collecting, model railroading, for example. All of these are pursued because of their intrinsic pleasure—the pleasure of the work itself—and their ability to focus one's concentration and creative energy. There is also the pleasure derived from the finished work—the ability to sit back and enjoy that which you have created. For builders of electronic kits, it was (is) the combined rush of putting it together and plugging it in and flipping the switch and having it actually work that sealed the deal with the likes of Heath and EICO and all the others.[1]

The proposition that assembling electronic kits can also teach electronics is an oft-cited benefit of kit building. I would argue that there is very little to it. Step-by-step instructions do nothing to explain the function of any particular component or its relation to all the others. Consider the absurd example of performing surgery with step-by-step instructions. You might become adept at doing appendectomies, but you would not know anything more about physiology or medicine as a result. In most cases, kit manufactures did not promote education as a reason for assembling their products. Mostly they promoted saving money.

Build it Yourself

Until the early 1920s or so, if you wanted a radio transmitter or receiver, you pretty much had to build it yourself. You could get parts at your local radio supply shop, though many hobbyists scrounged them from whatever sources could be found. And given the technology of the 1910s and 20s, you could, in some cases, build the parts yourself, from scratch.

Then, as now, some radio enthusiasts were more technically inclined than others, and for those less inclined, buying, scrounging, or building parts—let along designing circuits—could be daunting or impossible. Ready made broadcast receivers were widely available by 1920, of course, but they were expensive.

Milestone 1921: The first live radio broadcast of a baseball game.

It didn't take long for radio manufacturers to realize—as Howard Anthony would realize some 25 years later—that the market for radios would be much larger if only they were less expensive. The answer, of course, was kits. Kits would be less expensive because they would not be burdened by the cost of assembly. Kits would attract not only the less technical hobbyist, but also those of modest means and those who simply wanted a radio.

Kits showed up very early in radio magazines. Some of the earliest appear to have been offered by companies that manufactured and wholesaled basic radio components like coils and "condensers" (as capacitors were referred to then).[2] These companies sold parts to commercial manufacturers, so it was a logical step to collect their own parts into a kit and sell them directly to consumers. Whether

or not these kits included complete sets of parts or any kind of instructions is often not clear from the advertising. See the Tuska ad in Fig. 1.

Radio News for November, 1921
413
ASSEMBLE YOUR RADIO
Type 220—Price $75.00
Regenerative Tuner
Wave Length Ranges
180—375 Meters
375—825 Meters
Comprised of antenna variable, secondary variable, plate variometer, coupler, wave change switch.
Price unmounted, without cabinet, $41.50
Unassembled Tuner Made of Tuska Parts
The Tuska Moulded Variometers and Variocoupler. Sold unassembled, without cabinet at $27.50
LIST OF PARTS
2 Tuska Variometers $12.50
2 Tuska Dials 3.30
1 Tuska Variocoupler 7.50
1 Drilled and Engraved Panel 6.00
2 Pair Brackets ..... .70
1 Switch ..... .35
6 Switch Points ..... .35
6 Binding Posts ..... .72
10 Feet Connecting Wire ..... .08
Total $30.50
TYPE 223, $27.50
TUSKA VARIOCOUPLER
The Tuska Variocoupler is composed of moulded rotor, formica tubing, green silk wire and perfect mechanical construction. Primary 96 turns—Secondary 45 turns.
Price $7.50
TUSKA KNOB AND DIAL
For 3/16" or 1/4" shaft
Type 230—Price $7.50
Type 210—Price $1.65
Send 5 cents for our Bulletin No. 2 and Temporary Catalog
THE C. D. TUSKA COMPANY
265 HIGH STREET
HARTFORD, CONNECTICUT

Fig. 1. C. D. Tuska Company ad. In kits, Tuska found an additional market for the parts it made. (*Radio News*, November 1921, p. 413)

Saving money notwithstanding, rather quickly the idea that assembling your own radio could be fun also gained some traction, as illustrated by a 1922 ad for the unfortunately-named Sleeper Radio Company.[3] And unlike many ads for kits, Sleeper specifically said that complete instructions were included, Fig. 2.

Radio News for November, 1922
937
"The fun in radio is—building your own"
THERE'S no denying it's far more pleasure to build your own radio set than in just buying it ready made. When you make it yourself you know the purpose of every part. Experimenting to get distant stations becomes an absorbing game. You become an authority on radio to whom others look for advice.
The Sleeper Radio Corporation offers a wonderful series of Construction sets. All the difficult, tedious part of the work is done for you. You need only a pair of pliers, a screw driver, and a soldering iron to put them together, follow out the hook-ups, and get ready to tune in on distant broadcasting stations.
Each Sleeper Construction Set is packed in an individual box, complete to the last binding post. The set includes specially prepared instructions by M. B. Sleeper, Editor of Radio and Model Engineering. Every Sleeper Part is standard and interchangeable and can be used for further combinations to secure even greater range.
You can buy the Sleeper Construction Set described below, or any other Sleeper Set, at radio and electrical stores, for a fraction of the cost of a factory finished set. If your nearest dealer cannot supply you, write us and we will see that you are taken care of. If you will also enclose 50c. in stamps we will send you the book, "Design of Modern Radio Receiving Sets," which tells you how to build the latest types of radio equipment. We will also send you *free* the current issue of "Radio and Model Engineering" and a catalog of Sleeper Radio Construction Sets and Parts. THE SLEEPER RADIO CORPORATION, DEPT. 9, 88 Park Place, New York City.
Sleeper Construction Set, Type 2400 with two-step amplifier, Type 3100
PRICE $42.12.
This combination of the Compact Receiver, listing separately for $14.12 and the two-stage amplifier listing at $28.00, makes an ideal receiving equipment for all-around use. It gives all variation of wave-lengths of from 100 to 700 meters. The receiver is a one-tube set complete in itself, specially good for portable purposes. With the two-step amplifier the signal strength is increased powerfully, permitting the use of a loud speaker. The amplifier is equipped with three jacks so the detector can be used alone or with one or two stages of amplification. The best for all around service.
SLEEPER
Radio
CONSTRUCTION SETS

Fig. 2. Sleeper Radio construction sets ad. Sleeper Radio may have been the first to suggest that kit building could be fun. (*Radio News*, November 1922, p. 937)

Milestone 1922: Spark transmitters are a thing of the past.

Other incentives to build your own radio soon followed. A 1922 ad for Fremont Radio Sales Co. suggested, "You can't know Radio unless you wire your own set," as in Fig. 3.[4] A dubious claim, as discussed earlier.

Many of the kit ads ran only once,

Radio News for December, 1922

FREMONT — The Radio Advisor — FREMONT

Know Radio — DECEMBER 1922 — Know Radio

"Build Your Own Set," Says Radio Expert

KNOWLEDGE OF RADIO GIVES GREATER ENJOYMENT TO FANS

"You can't know Radio unless you wire your own set," says Mr. Singer; Cites cases where buyers of complete sets unwired outfits to learn functioning of parts

"Every Radio Enthusiast must build his own receiving set before he will really understand the operation and enjoy the best results from his receiving set." So says Mr. E. Singer, associate member of the I. R. E. and A. I. E. E.

Mr. Singer is considered by the Radio Fraternity as one of its foremost technical and practical members. He has been of great assistance to the Radio fan through his many articles on Radio which have appeared in leading Radio magazines throughout the country. Consequently his words amount more than passing interest and it was only natural that he should be asked for further reasons why he holds to belief.

"Ask any one who has played with Radio for any length of time," he says, "and I'll wager each and everyone will tell you, he learned the fundamentals of radio from wiring up his own set.

Pleasure Comes with Knowledge

"With the fundamental knowledge of radio comes greater pleasure, and better results, for though the wiring of your own set, you have learned the relation which the various parts bear to each other. Consequently, you are able to operate your set more efficiently.

Outside View of the Fremont A. W. No. 1—$35.00 Set

"Personally I know of several cases where radio enthusiasts a few months ago, accepted in radio sets sold to Boosters, stuck to their guns, that on account of being unfamiliar with the fundamentals of radio, they were unable to operate the sets properly. These same enthusiasts today, now that a wonder other they made their first investment, are getting double the pleasure from their sets.

They Get Experience

"Other Boosters shortly after installing these sets they learned that radio is there was more of a mystery than ever, the reason is the fact that they did not know the right functioning powers of the various parts. They read more books on radio only to find the numerous technical terms deepened the mystery.

"Then, to some it occurred that the greater knowledge could be gained by taking apart their sets and receiving them, making note of the relation which each part bore to the other. Others purchased complete sets unassembled which they put together themselves. Those who followed this latter help us great and laudable to say. Their sets are very operated more effectively.

Buy an Unwired Set

"Quite frequently I am asked to name one who has just become interested in radio as to what set to buy. Questions there are many sets on the market today, made by reliable manufacturers, that give satisfactory results. Yet I never advise the purchase of a completely wired set.

"A few years ago I was an amateur in radio work. I learned the fundamental principles from wiring my own set. My experience and the experience of those radio enthusiasts I mentioned before always should purchase the kit—you can't know radio unless you build your own receiving set."

Essential Parts Needed for Building Tube Set

Here's a list of some essential parts necessary to build your own receiving set. Loop Wave Variometer, Variable Condenser, Socket, Rheostat, Panel, Cabinet, Binding Posts, Jack, Plugs, Grid Leak, Fixed Condenser.

A Radio catalog containing a complete list of Radio parts can be obtained, free of charge, from The Fremont Radio Sales Co., 50 Church Street, New York City.

He's Happy Now—He Read Our Ad

Now the Proud Owner of a Tube Set Which He Understands

By ALBERT E. DONNELLY

About July, 1921, I became interested in radio and, like numerous other people, purchased a crystal set. I thought that my set was great after talking to fellows who were having all sorts of trouble with their crystals and tuning.

After reading the magazines and books on radio, naturally, I longed for a tube set. But the question came up, how will I get the money to buy this set under needs? Finally I decided to build my own. Then the fun began. First trying to get the right circuit, tuning it, and so forth, learning what the various parts were going. This kept up for a few weeks. Then the gates opened to the different circuits to use the apparatus, which I would be confronted with such advice as "Don't buy that article it leaks," "Get the transformer in next," and many various other discouraging advice.

In the end I saw that about 3 times exactly what kind of a circuit I wanted and the name of the apparatus, my bookshelf was taking a change.

This trouble was solved when an ad in a magazine attracted my attention. It was a complete set unassembled. The ideal something, no worry about the circuit, design or apparatus. Home drilled and everything. And results, they were great.

UNASSEMBLED SET NOW READY FOR MARKET

Fremont Radio Sales Co. Devises Plan to Aid Radio Enthusiasts

Complete Radio Receiving Set, unassembled, can now be obtained at big savings from a responsible Radio House. This concern is the Fremont Radio Sales Company, located at 50 Church Street, New York City. They manufacture a tube set which is shipped, unassembled, ready to be put together. This set is the Fremont A. W. No. 1 Set and can be bought direct for $35.00. Each part is wrapped separately. All parts are furnished except Detector tube and Phones. Panels are drilled and every necessary part, including diagrams for wiring are furnished with each set. Here is a tuner and detector combination which receives broadcasting news and concerts within a range from 150 to 3,000 meters.

Interior View

Guarantee Apparatus

Fremont apparatus carries a guarantee against all mechanical or electrical imperfections. Every instrument is thoroughly tested before shipment.

All enthusiasts for detail wishing on the Fremont A. W. No. 1 Receiving Set should be sure to Postal Money Order or Express Money Order and should be addressed to Fremont Radio Sales Co., 50 Church Street, New York City.

Order today and write name and address clearly to insure prompt shipment.

FREE RADIO CATALOGUE

Be sure to send for the fully illustrated Radio catalog containing various types of knock-down sets, issued free of charge, by the FREMONT RADIO SALES CO. at 50 Church Street, New York City.

1248

Fig. 3. *The Radio Advisor* cover page. It may seem intuitively obvious that building a radio set could make you smarter, but there probably isn't much to it. Heath never really stressed the educational angle, except for very specific products, generally for kids. (*Radio News*, December 1922, p. 1248)

suggesting a number of possibilities: that quality was lacking, that fewer kits were sold than had been hoped, that the companies were never very serious about kits to begin with, perhaps, or that the companies quickly went broke through mismanagement or other reasons.

A major reason many kit makers didn't last very long may have been that they did not anticipate having to provide technical support. There is, after all, more to selling kits than throwing a few parts in a box and running an ad. Even if clear instructions were included (not always a given), there would always be people who were unable or unwilling to follow them. And when their kit went up in smoke, they called for help. Businesses that had not foreseen this eventuality probably decided that kits were more trouble than they were worth.

Nevertheless, through the 1920s and early 30s, kits became more numerous, and were offered by companies with names that may be more familiar than Sleeper. These included Hammarlund, shown in Fig. 4, National, Thordarson, and Silver Marshall, for example.[5]

Radio News for December, 1926
725
"How To Build It" Book
25c
$63.05
Complete Parts
(less cabinet)
Hi-Q Foundation Unit
$10.50
Associate Manufacturers
Hammarlund Performance Means
A New Measure For All Radio
THE Hammarlund-Roberts Hi-Q is an outstanding example of scientific radio engineering. No ordinary standards of tone, selectivity or volume, can be applied to this new receiver.
In designing this Hi-Q Receiver, the Hammarlund-Roberts Board of Engineers representing twelve nationally known manufacturers, had at their disposal the finest experimental laboratories—and no handicap in building to establish specifications or to a set price.
This concentration of the leaders in the perfection of one radio Receiver has developed entirely new features that produce results unknown to the average radio man. Automatic variable coupling gives maximum and equal amplification and selectivity over the entire tuning range. Stage shielding eliminates coupling between stages, prevents oscillation and increases selectivity. Two dial control simplifies tuning.
ANYONE CAN BUILD THE HAMMARLUND-ROBERTS Hi-Q
All the research, the selection of parts, the exact placing of units, has been worked out in advance for you. And you have a receiver that will equal an eight tube set—simplicity of design and operation hitherto unthought of—all at less than half the price you would pay for a factory made set of anywhere near equal efficiency.
Hammarlund
ROBERTS
Hi-Q
Hammarlund-Roberts
1182-C Broadway
New York

Fig. 4. 1926 Hammarlund HiQ receiver. Hammarlund, minus Roberts, would go on to become one of the biggest names in amateur radio—but not with kits. The company made only a few kits through the late 1920s. (*Radio News*, December 1926, p. 725)

Milestone 1928: The 80, 40, 20, and 10 meter amateur radio bands are codified by international treaty.

Allied Radio

In 1928, the Allied Radio Company was formed. Based in Chicago, Allied quickly established itself as one of the largest distributors of radio components and radio-related consumer products in the United States. In addition to selling parts from major manufacturers, Allied created its own label of components and fully assembled consumer products (mostly "all-wave" and broadcast receivers, and Hi-Fi amplifiers) and sold them under the brand name Knight.

Allied published a yearly catalog which included, among other things, kits available from many different manufacturers: Victoreen of Fig. 5, Aero of Fig. 6, HFL Isotone, Tyrman, Scott,

713
"I wanted to be sure of Quality so I built a VICTOREEN"
T·W·GROGAN President
The T·W·GROGAN COMPANY
Union Mortgage Bldg. Cleveland, O.
Frank expressions of approval from the lips of men who know, are the best evidence of Victoreen superiority! Those who have spent much time and money in an effort to achieve the ultimate in radio, eventually find complete satisfaction in a Victoreen Super. Tone brilliancy, distance, knife-like selectivity and simplicity of assembly. These are the outstanding qualities which account for the great wave of Victoreen popularity in high places.
You can build a Victoreen "Super" and be assured of quality results. Send today for the 1928 blue print of the Victoreen circuit, there is no charge.
The GEORGE W. WALKER Co.
MERCHANDISERS OF VICTOREEN RADIO PRODUCTS
2825 CHESTER AVENUE CLEVELAND OHIO

Fig. 5. 1927 Victoreen receiver. Victoreen made only a few kits, but would become well known for making zillions of Geiger counters for the government's civil defense program of the 1950s. (*Radio News*, December 1927, p. 713)

Aero Short Wave Kit
The Aero standard three tube short wave receiver for either A.C. or D.C. tubes utilizes a regenerative circuit which has been proven by years of excellent results in the hands of amateur operators. The same special audio amplifier is supplied as is used in the Aero 7-29 and other Aero high grade kits so that excellent tone quality may be assured when receiving distant stations. Kit is complete with nothing else to purchase.
Can be adapted to cover range of from 15 to 125 to 550 meters with Aero coils 4 and 5 which are interchangeable.
European broadcasting heard on test. Comes complete in factory sealed kit without cabinet but with panel, sub panel and illuminated dial. Wt., 16 lbs.
No. 8761. Aero Kit No. 10 for A.C. Tubes.
No. 8762. Aero Kit No. 11 for D.C. Tubes.
List on each $49.95
Your Price .....
$29.37

Fig. 6. 1929 Aero short wave receiver. Before it began selling its own kits, Allied Radio sold a wide variety of kits from many different sources. (Allied Radio Catalog, 1929)

Hammarlund Master HiQ-29
The HiQ-29 presents a new design and increased efficiency of the tremendously popular HiQ Six. Two circuits, designed for storage battery or A.C. operation.
Completely Shielded
The radio frequency circuit is stage shielded. The design of the assembly is such that the R.F. tubes themselves are individually electro-statically shielded from the tuning units and inductances. Greatest efficiency is obtained with tremendous radio frequency amplification.
New Illuminated Drum Dials
Incorporates the latest Hammarlund illuminated tuning control features. The receiver is extremely easy to assemble, furnished with foundation unit and steel chassis.
HiQ-29 Master Foundation Unit
Contains drilled and engraved panel, three complete aluminum shields, drilled steel chassis, shafts, binding posts, strips and all essential hardware and wire.
No. 2702. List $16.50. YOUR PRICE .....
$9.70
A. C. MODEL
COMPLETE PARTS FOR BUILDING THE A.C. MASTER HIQ-29 FOR ELECTRIC OPERATION: Five Hammarlund .00025 condensers, one Hammarlund HiQ-29 coil set, two Hammarlund drum dials, three Hammarlund RFC-85 R.F. chokes, six Benjamin 9040 sockets, one Sangamo, .00025 condenser, one Sangamo .001 condenser, one Carter No. 11 Hi-Pot, two Thordarson R 200 transformers, one Thordarson R 196 choke, one Thordarson R 171 compact, one Thordarson 2619 filament transformer, six Parvolt .5 by pass condensers, one Parvolt 4, by pass condenser, one Parvolt 2, by pass condenser, one Parvolt 1, filter condenser, one Parvolt 2, filter condenser, one Parvolt 4, filter condenser, one Parvolt 2, filter condenser, one 1½ meg. resistor, two ½ meg. resistors, one Yaxley 612 cable connector, one pair Yaxley insulated tip jacks, one Electrad HiQ-29 resistor, two Eby binding posts, one HiQ Master Foundation Unit.
No. 8785 Total List $151.80. YOUR PRICE .....
$89.26
D. C. MODEL
FOR STORAGE BATTERY OPERATION. Five Hammarlund .00025 midline condensers, one Hammarlund HiQ-29 coil set, two Hammarlund drum dials, three Hammarlund RFC-85 R.F. chokes, five Benjamin 9040 sockets, one Sangamo .00025 condensers, one Sangamo .001 condenser, one Carter No. 113 Hi-Pot, two Thordarson R 200 transformers, four Parvolt .5 by pass condensers, one 1½ meg. resistor, one Yaxley 660 cable connector, one pair Yaxley insulated tip jacks, two 1A amperites, one 1/2 amperite, two Eby binding posts, one HiQ-29 Master Foundation Unit.
No. 8786. Total List $99.50.
Your Price .....
$58.50

Fig. 7. 1929 Hammarlund HiQ-29 receiver. The Master HiQ-29 was the last of Hammarlund's kits. The fully assembled Comet was released in 1931. (Allied Radio Catalog, 1929)

Hammarlund of Fig. 7, Browning-Drake, Remler, National and others.[6] All offered a variety of receiver kits varying in cost and sophistication.

Milestone 1929: America's Great Depression begins.

While fully assembled broadcast and shortwave receiver products continued to sell fairly well, kit-form products took a hit with the onset of the Great Depression in 1929, with ads for kit products nearly disappearing. While the downturn in the economy would grind on for many more years, the decline in kit offerings would not last long.

The year 1932 was arguably the lowest point of the Great Depression, but you wouldn't guess that by looking through the popular magazines of the time. Just based on the amount of advertising, you might think that 1932 was business as usual.

One of the most familiar and respected names in amateur radio appeared for the first time in the January 1932 issue of *QST* magazine.[7] Arthur Collins, soon to be the founder of the Collins Radio Company, placed an ad for a transmitter in kit form. In this first ad, his company is called Radio Laboratories. The model of the transmitter kit being offered in the ad of Fig. 8 is not stated, but it is not the 4A transmitter, Collins first smallish "low cost" transmitter, which used a pair of 46 dual-grid output tubes, and was released in December 1933.

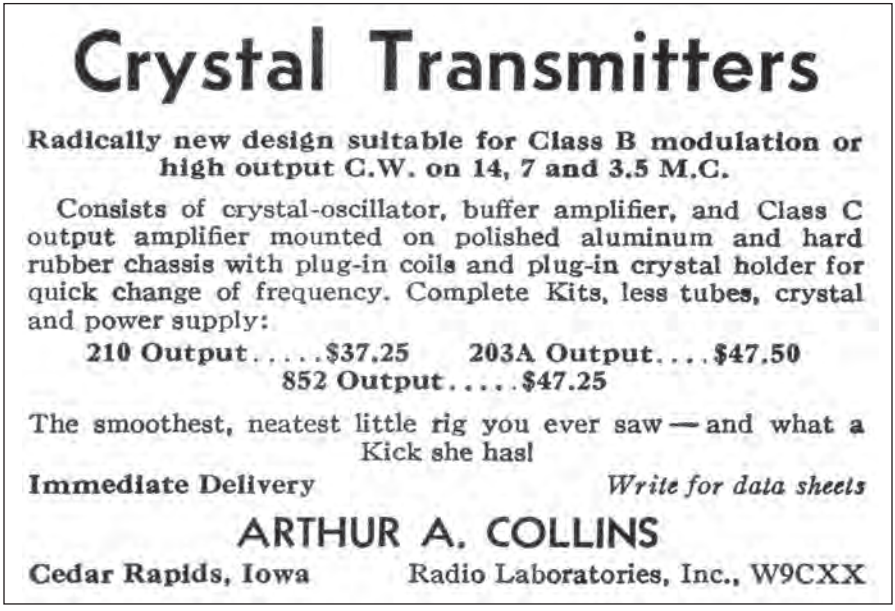

Crystal Transmitters
Radically new design suitable for Class B modulation or high output C.W. on 14, 7 and 3.5 M.C.
Consists of crystal-oscillator, buffer amplifier, and Class C output amplifier mounted on polished aluminum and hard rubber chassis with plug-in coils and plug-in crystal holder for quick change of frequency. Complete Kits, less tubes, crystal and power supply:
210 Output.....$37.25 203A Output....$47.50
852 Output.....$47.25
The smoothest, neatest little rig you ever saw — and what a Kick she has!
Immediate Delivery
Write for data sheets
ARTHUR A. COLLINS
Cedar Rapids, Iowa
Radio Laboratories, Inc., W9CXX

Fig. 8. 1932 Collins transmitter. To quote original Tonight Show host, Steve Allen, "This could be the start of something big." Art Collins ran this ad for what may have been his first product, and probably the only kit Collins ever offered. It is not clear exactly what transmitter model was behind this ad."…and what a kick she has!" (*QST*, January 1932)

Kit-Form Test Equipment

Test equipment construction articles were a mainstay of the popular magazines. Every month, without fail, there were articles for test equipment of all description. Yet there are no examples of commercially available kit-form test equipment products until the early 1930s. A casual review of *Radio News* and *Radio-Craft* magazines suggests the first piece of commercially available test equipment in kit form was advertised in the January 1933 issue of *Radio News*, shown in Fig. 9.[8]

The unit barely qualifies as "test equipment" because it is actually an adapter for older tube checkers and "set analyzers," designed to provide compatibility with 6 and 7 pin tubes. Still, it was "electronic" in a broad sense and was available in kit form. The adapter was sold by Coast to Coast Radio, but what company actually made this kit is unknown.

4-5-6-7 PRONG All Purpose TUBE CHECKER,
SET ANALYSER Medium and ADAPTER
Modernizes any Make and Model Set Analyzer or Tube Checker
Permits ALL-PURPOSE Testing of ANY 4, 5, 6 and 7 prong tubes with ANY Tube Checker, Set Analyzer, or Separate Voltmeter and Milliammeter. Each tube prong circuit has a removable jumper. Complete Kit, as Illustrated with 7 to 6 Adapter and Instruction Sheets.....$3.95
FACTORY WIRED.....4.95
SET OF THREE TUBE CHECKER AND SET ANALYZER Adapters.....2.10
COAST TO COAST RADIO

Fig. 9. 1933 Coast to Coast tube checker adapter. Whether or not this adapter qualifies as a piece of test equipment is debatable, though it is the first ad for a test-equipment-related kit product found by the author. (*Radio News*, Jan 1933)

A better, and perhaps more "pure" example can found in the January 1933 issue of *Radio-Craft.* This unit was unusual both in design and in how it came to be sold.

The device was a meterless tube tester offered in an ad by Leeds, which was based on a construction article appearing in the very same issue, as shown in Fig. 10.[9] How convenient. What appears to have happened is this: the publisher of the magazine tipped off Leeds regarding the upcoming article so that Leeds could offer a kit of parts for sale in the same issue. Numerous other examples of this strategy can be found in the months that followed, though not from Leeds. Whether this was a "pay to play" scheme, or something less calculated is unknown, but it was certainly a win-win concept.

The volt-ohm-milliammeter (VOM) was one of the very first kit-form test equipment products available, in part because they were quite useful, relatively uncomplicated, required only a few parts, and were therefore, relatively inexpensive. Two commercially available kit-form VOMs appeared in August 1933; one in *Radio News*, shown in Fig. 11, and the other in *Radio-Craft*.[10] Other VOM kits would soon follow. These instruments were not based on articles in the magazines. More sophisticated test equipment, like oscilloscopes and signal generators, would take a little more time.

In 1934, Allied entered the kit business itself with a simple two-tube receiver called the "DX-ER," shown in Fig. 12. It covered from 16 to 200 meters.[11] (In those days, frequency coverage was virtually always described in meters, not kilocycles or megacycles.) The set sold for $5.25, but the coils, tubes, batteries, and headphones were sold separately—as was common practice. With all the options, the price was $12.18, or about $235, adjusted for inflation. Still, it was less expensive than any other receiver in the catalog.

By 1935, a number of manufactures were advertising test equipment kits including so-called "set analyzers"

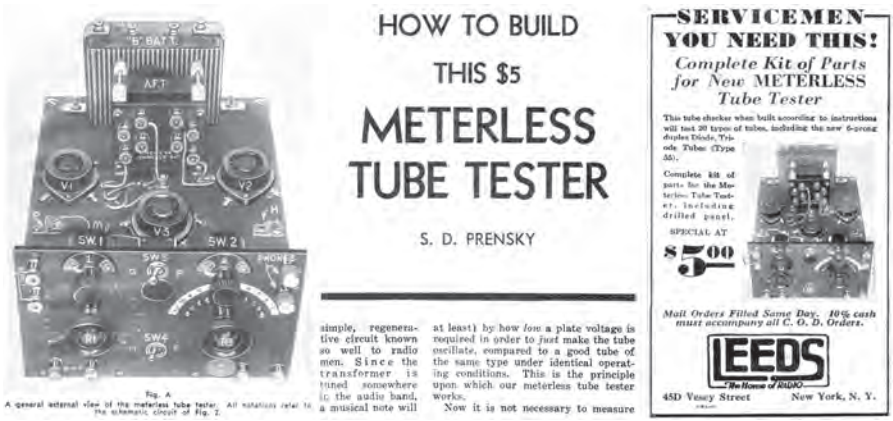


Fig. 10. 1933 Meterless Tube Tester. Part of the *Radio-Craft* construction article (left) and Leeds' ad in the same issue. A cozy arrangement. There are many other examples. (*Radio-Craft*, January 1933)

WESTON METERED
UNIVERSAL TESTER
Assemble your own Tester Easy to Build Takes one hour
Has Weston Meter—1,000 ohms per volt. AC or DC Volt Range, 5 - 10 - 50 - 100 - 250 - 500-1000. Milliampere Range: AC-1; DC, 1-10-25-100. Ohm Scale, 1000 - 10,000 - 100,000. (Resistance of 1 ohm can be read). Charts for impedance and capacity measurements. Complete set of parts all ready to assemble and wire, include enamel finished aluminum case, engraved panel, binding posts, tip jacks, switches, brackets, resistors and shunts. Simple wiring diagram with complete instructions for quick assembly included with each kit. An extraordinary value. $50.00 List. DEALER'S PRICE, $24.95 Complete.
WRITE FOR FULL DETAILS
This TESTER is the first unit of a complete testing kit in 1 convenient case. Companion ANALYSER and OSCILLATOR units also available. Assemble as required. Save time and make money with this tester. Satisfaction guaranteed. Write
$24.95
UNIVERSAL METER WORKS
414 North Leavitt St., Chicago, Ill.

Fig. 11. 1933 Universal Meter Works universal tester. The $24.95 price for this kit is for dealers. That makes the retail price closer to $50, or $1,000 adjusted for inflation. Weston and Triplett both had assembled products in the $20 range, while second-tier products were in the $10 range. (*Radio News*, August 1933)

KNIGHT 2 TUBE
DX-ER SHORT WAVE
RADIO
KIT
ALLIED offers a complete kit of quality parts for building an inexpensive yet efficient two tube short wave receiver. Only first grade parts are used in this go-getter to assure real performance. Simple and easy to build; inexpensive to operate. Uses type 30 tubes in an efficient regenerative circuit with one audio stage. Amateurs, commercial stations, short wave broadcasts and many foreign stations are brought in by this efficient receiver.
F9250. A complete kit of parts for the construction of the DX-ER including panel, baseboard, sockets, condensers, resistors, shielded transformer, dials, etc., with complete wiring diagram. Coils, tubes, batteries and phones are extra and are listed below.
YOUR NET PRICE..... $5.25
F1490. Set of 4 low loss coils for the DX-ER covering from 16 to 200 meters.
YOUR NET PRICE..... $1.58
F9249. Tube and battery kit, consisting of 2 Cunningham 30 tubes, 2—1½ volt dry cells and 2—45 volt "B" Batteries. NET $3.70
F1917. Brandes Phones. 2400 ohms.
YOUR NET PRICE $1.65

Fig. 12. 1934 Knight DX-ER short wave receiver. Allied's first kit product. The company's "Knight" brand would not become "Knight-Kit" until 1957. (Allied Radio Catalog, 1934)

or "set testers." These relatively simple pieces of test equipment bloomed in the early 1930s. These were generally attaché case-sized instruments usually containing a VOM and a simple tube tester. A Grenpark unit is shown in Fig. 13.[12]

Modern Testing Instruments
that give Accurate Measurements,
Longer Service and are Lower-Priced
DEPENDABLE ANALYZER MODEL 5414
A new efficient analyzer unit combining many prominent features:—2000 ohm per volt sensitivity—Self contained 3 range ohmmeter—NO external batteries required—Eliminates referring to charts and fussing with connecting plugs—Protection against obsolescence—Entire metering system is independent of circuit switching—Free Reference Point testing—Instantly makes all Point to Point measurements between ANY TWO POINTS.
Model No. 5413 Analyzer—Ohmmeter: 0-2000; 0-200,000; and 0-2,000,000—Voltmeter: 0-5; 0-50; 0-250 and 0-750—Microammeter: 0-500—Milliammeter: 0-50—2000 ohms per volt; 3¼" meter; 2% accuracy. COMPLETE, ready to operate
KIT $21.50
$24.95 NET
Model No. 5414—Same as above with additional Milliammeter: Ranges 0-50; 0-250. Bakelite case; meter 3¾"; 2% accuracy. All shunts and multipliers individually calibrated to within 2%. Model 5414, COMPLETE, ready to operate $28.95
KIT $24.50
DEPENDABLE MULTITESTER MODEL 403-A
Service men and dealers highly praised the Model 403 Multitester—and it deserved praise. But the new improved Model 403-A "DEPENDABLE" MULTITESTER insures even greater satisfaction at less cost. Embodying every feature of the former model, No. 403-A is more compact, having been designed as a companion instrument to the new Model 501 ANALYZER UNIT described below.
2,000 ohms per volt. Accuracy within 2 per cent in D'ARSONVAL type moving coil meter. 3-range 0-2,000,000 ohmmeter; 4-range 0-5-50-250-750 voltmeter; 0-500 microammeter.
$13.95 NET
COMPLETE, ready to operate
KIT $10.65
DEPENDABLE TUBE TESTER MODEL 304
Accuracy is essential in tube testers. Adaptability for all present and future needs is valuable. Convenience and good looks are desirable. But high price isn't necessary.
The new Radio City "DEPENDABLE" Tube Tester provides all of these features at the lowest cost. And their reputation with service men and dealers is unsurpassed. Complete units, ready to operate, or money-saving kits.
The only tube tester showing leakages above one-million ohms. Neon-light indicator. "Good-Bad" meter. Tests all today's tubes and provides for 50% increase. One-button operation. Etched metal panel. Leatherette case. Counter and portable models
$15.65 KIT
$19.95 Ready to Operate
We Issue No Catalog
All orders are F.O.B. New York. Terms: A deposit of 20% is required with every order. Balance may be paid on delivery. DEDUCT 2% IF FULL AMOUNT IS SENT.
GRENPARK COMPANY
101 Hudson St. Dept. RC New York, N. Y.

Fig. 13. 1935 Grenpark test instruments. In this ad, kit prices are listed in the fine print. The large-print prices are for fully assembled units. Careful examination of the ad reveals that the instruments were made by Radio City Products, a prolific electronics manufacturer of the time. (*Radio-Craft*, April 1935)

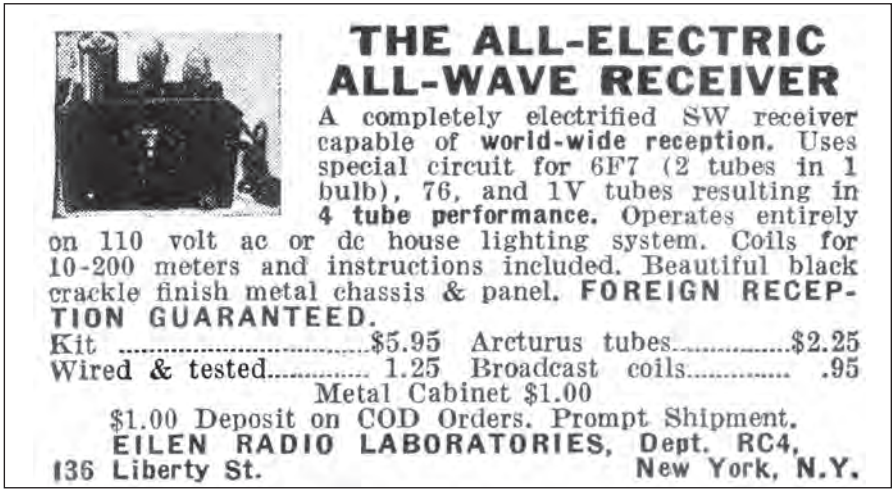

THE ALL-ELECTRIC
ALL-WAVE RECEIVER
A completely electrified SW receiver capable of world-wide reception. Uses special circuit for 6F7 (2 tubes in 1 bulb), 76, and 1V tubes resulting in 4 tube performance. Operates entirely on 110 volt ac or dc house lighting system. Coils for 10-200 meters and instructions included. Beautiful black crackle finish metal chassis & panel. FOREIGN RECEPTION GUARANTEED.
Kit .....$5.95 Arcturus tubes.....$2.25
Wired & tested..... 1.25 Broadcast coils..... .95
Metal Cabinet $1.00
$1.00 Deposit on COD Orders. Prompt Shipment.
EILEN RADIO LABORATORIES, Dept. RC4,
136 Liberty St. New York, N.Y.

Fig. 14. 1935 Eilen Radio Laboratories receiver. In retrospect, this ad is a little amusing in emphasizing that the receiver is "completely electrified." The tubes, broadcast coils, and even the metal cabinet were all sold separately. Don't forget, "foreign reception guaranteed." (*Radio-Craft*, April 1935)

Eilen Radio was among a multitude of small players in the 1930s. The company made kits and fully assembled products, shown in Fig. 14, until it merged with another small player in 1937.[13]

Milestone 1935: The new Heath company is formed.

Allied began to expand its Knight brand of kits very quickly. The Super-Gainer short wave receiver of Fig. 15 was advertised as easy to build, so as to appeal to amateurs and beginners.[14]

Oscilloscopes (originally referred to as oscillographs) were, until the late 1930s, expensive and exotic pieces of equipment. The earliest reference found for a fully assembled oscilloscope was from the June 1934 issue of *Radio Electronics* magazine, with an ad for the three inch National "Triumph" model scope ($34.95, or $680 today). In 1937, three manufacturers introduced kit-form oscilloscopes: Thordarson, Supreme, and Transformer Corporation of America. All of these used RCA's newly developed 913 one inch cathode ray tube. Supreme was well-established in assembled test equipment products, and American Transformer had introduced a series of kit-form public address amplifiers the previous year. Thordarson, a company better known for its line of transformers, was an early player in kits.

Thordarson's scope sold for $24.92, including a two inch magnifying lens, as in Fig. 16.[15] For comparison, RCA's fully assembled model 151 and Clough-Brengle's model 105, were both priced at about $48.00.

In addition to its scope, Thordarson also released a Hi-Fi amplifier, and starting in 1938, it introduced several

KNIGHT 3 TUBE SUPER-GAINER
A GREAT NEW JONES SHORT WAVE AMATEUR COMMUNICATION SUPERHET
AN EXCLUSIVE ALLIED "SCOOP"
Here is the "hottest" Amateur S.W. Receiver available today. Brand new—brilliantly designed by Frank C. Jones to give the Amateur a real Communication receiver at a price that has never before been duplicated in Amateur history. The Super-Gainer has everything—by the use of regeneration at two frequencies, three tubes do the work of six. Features incorporated are: real Bandspread tuning; built-in Beat Oscillator; iron-core variable coupling I.F. transformer; regenerative 1st and 2nd detectors; real selectivity and sensitivity for both C.W. and phone work. Unique design makes the Super-Gainer a powerful S.W. set, exceptionally stable in operation. The amazingly low price of the Super-Gainer places it within the easy reach of every Amateur in the country for use either as a main station or stand-by receiver.
RCA LICENSED
DUAL REGENERATION—ELIMINATES I. F. STAGES
A 6C6 regenerative first detector gives as much selectivity as two good R.F. stages; a 75 H.F. oscillator is electron-coupled through suppressor-grid injection to the first detector. One section of the 79 dual-triode is used as a regenerative second detector which boosts the gain tremendously and as beat oscillator, while the other section is used as the A.F. amplifier. An iron core 465 K.C. I.F. transformer is used between first and second detectors; and gives gain and selectivity almost equal to two ordinary I.F. stages. All tubes are shielded. Has 2 gang double-spaced bandspread tuning condenser. See illustrations for ingenious construction design permitting the shortest possible leads. The Knight-Jones Super-Gainer is available completely assembled, wired and tested, and fully licensed by RCA and Hazeltine, or in kit form for easy home construction.
EASY TO BUILD
BATTERY-OPERATED SUPER-GAINER KIT
H9505. Complete kit of all parts for building the Super-Gainer for battery operation. Includes 49-80 meter coils. Requires 6 V. "A" and 135 V. "B." and 1—6C6, 1—76 and 1—79 tubes. NET $14.95
Super-Gainer Kit For AC-DC Operation
H9507. Complete Super-Gainer Kit for 110 Volt AC-DC operation. Includes 49-80 meter coils. Requires 1—6C6, 1—76, 1—79, and 1—12Z3 tubes. NET $18.25
H9506. The battery operated Super-Gainer completely wired and tested. With 40-80 meter coils but less batteries and tubes. NET $18.65
H9508. The AC-DC Super-Gainer completely wired and tested. With 40-80 meter coils. Less tubes. NET $21.95
EXTRA S. W. COILS
H9509. 4 sets of coils to cover 10, 20, 40 and 160 meter amateur and all S. W. broadcast bands. NET $3.30
SEND FOR FREE CIRCULAR
Rear View

Fig. 15. 1936 Super Gainer receiver. The "Jones" referred to in the ad is Frank C. Jones, well-known radio engineer and author of a number of books including the *Radio Handbook* (later the *Jones Radio Handbook*) series started in 1935. (Allied Radio Catalog, 1936)

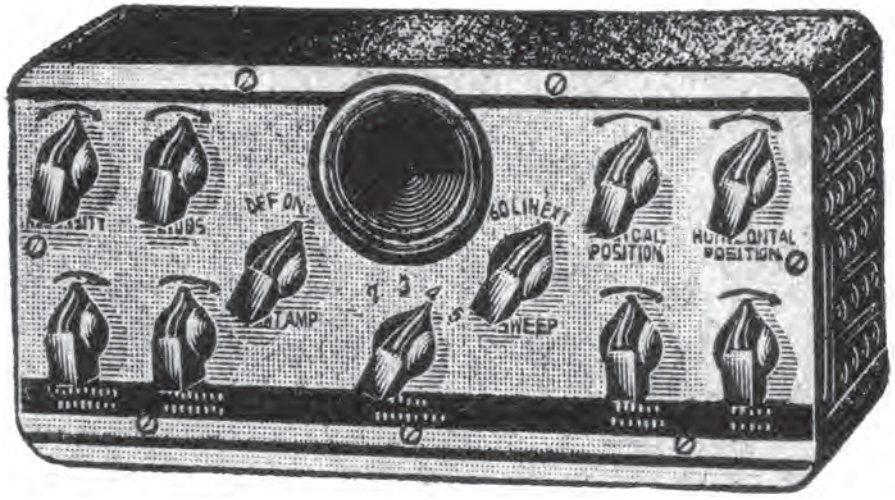


Fig. 16. 1937 Thordarson scope. Thordarson's scope was one of three released in 1937, the first scope kits on the market. All used RCA's new 913 one inch cathode ray tube. (Radio's Master Catalog, 1937)

kit-form amateur radio transmitters. The company's last kit products were introduced in 1940.

These three oscilloscope may represent the first pieces of kit-form test equipment beyond Universal's simple VOM of 1933, and clearly illustrates the price burden imposed by the cost of assembling a ready-made piece equipment.

Also in 1937, a company named Utah Radio Products (based in Chicago) introduced two kit transmitters for CW, shown in Fig. 17, and "phone."[16] Utah advertised a scheme it called "Add-A-Unit," allowing its 80 watt transmitter to be incorporated later into a 400 watt model.

A multitude of other companies, large and small, sprang up around this time. These include Aerovox, Try-Mo, All-Star, Kenyon Transformer, Experimental Radio Labs, Harvey Radio, Amplex Radio, and Alan Radio. Each offered kits of one kind or another.

By this time, Allied had expanded its line of kits to ten models, mostly receivers. The company advertised an improved version of its Super-Gainer model, shown alongside a 14-tube receiver kit made by Meissner, both shown in Fig. 18. And the

NEW UTAH 80 WATT CW TRANSMITTER KIT

Here is the answer to your new transmitter problem. For the beginner it's an ideal starting rig, a base on which to build to a complete 400 watt station. For the advanced Amateur it's a peach of an auxiliary unit to allow operation on several bands without disturbing the "big rig." It's new and up-to-the-minute; uses a 6L6 as crystal oscillator and a parallel 6L6 RF amplifier. Will deliver full 80 watts to the antenna. Attractive steel cabinet 18"x16"x9½" is finished in black crystal. Circuit design produces maximum "sock" without excessive power requirements. Easy to assemble; all drilling and punching already done for you; in fact the kit comes to you with many of the parts mounted in place. All parts carefully selected; power supply units have ratings that will insure maximum performance even under continuous operation. Don't delay building your new rig—start your Utah Add-A-Unit transmitter with the 80 watt unit now. Kit comes to you complete and ready for assembly.

A10336. Complete Kit, less only tubes, crystal and meters.
NET **$49.75**

And that isn't all—more Utah kits are coming to enable you to build the complete 400 watt CW-Phone rig. ALLIED will have them as fast as they are released. Write for literature and details.

Fig. 17. 1937 Utah transmitter. Chicago-based Utah Radio made a few kit transmitters in 1937, but never followed up with more, choosing instead to focus on speakers and transformers. (Allied Radio Catalog, 1937)

Latest "BUILD YOUR OWN" Kits
KNIGHT SUPER-GAINER S.W. KIT
With 4 Metal Tubes
An extremely efficient, easy-to-build four tube short-wave receiver. Latest design, improved circuit uses 4 all-metal tubes to give 7 tube performance. Exceptional sensitivity and selectivity results from the use of regeneration in the first and second detector stages; single-signal action on C.W. signals. The new 6L7 mixer tube, with special injector grid, allows absolute decoupling between oscillator and first detector, besides providing an extreme increase in sensitivity. Features: Bandspread tuning, dual regeneration control, iron core I.F. transformer, Isolantite coil sockets and adequate shielding. Low current drain allows the use of either batteries or the special A.C. power supply listed below. Complete kit includes punched chassis base and front panel, special shield, tube and coil sockets, resistors, condensers, hardware, complete diagrams and instruction, etc. Requires 1—6L7, 1—6C5, 1—6F5 and 1—6F6.
$14.50
A9505. Complete kit of parts with 10 meter coils, less tubes. NET
A9506. SET OF COILS. 8 coils, to cover the 10, 20, 40 and 160 meter bands, with adequate overlap for short wave broadcast band coverage. NET
$3.40
A. C. POWER SUPPLY FOR SUPER-GAINER
A9507. Complete kit of parts. Output 240 V. D.C. and 6.3 V. at .6 A. Kit includes punched chassis base, transformer, chokes, condensers, sockets, cable, diagrams, instructions, etc. Requires 1—80 tube (not supplied). NET
$4.95
NEW KNIGHT VOLUME EXPANDER KIT
A sensational new device for giving back to your loudspeaker all the fine points of music originally broadcast by the orchestra at the studio. True reproduction can be realized and depth can be recreated because the volume expander serves to further amplify fortissimo passages and make the pianissimos softer. Easily attached to any radio set or amplifier. The degree of expansion is controllable. Complete kit includes all necessary components for building. Uses 1—6L7, 2—76's and 1—80 tube not supplied.
A9508. Complete kit, less tubes. YOUR PRICE
$7.95
MEISSNER NEW 14 TUBE ALL-WAVE KIT
• 5 WAVE BANDS—3.8 TO 555 METERS
• ACCURATELY BALANCED AND ALIGNED TUNING ASSEMBLY
• CALIBRATED 5 INCH AIRPLANE DIAL, WITH MICROMASTER BAND SPREAD
A powerful 14 tube "Communications" receiver kit. Especially designed for Amateurs and set builders who want splendid results over all the bands. Starts at 5 meters and includes all the Amateur and broadcast bands. Some of the features are: Crystal Filter—Beat Frequency Oscillator with cut-out switch and pitch control—Noise Silencer Circuit—Variable Electrical Band Spread—Amplified A.V.C.-Variable Sensitivity Control—Iron Core I.F. Transformers—Audio Volume Control—P. P. Beam Power Output Tubes, etc. The completely wired and accurately balanced and aligned tuning assembly includes the Meissner Multi-Wave coil assembly, band change switch, variable gang condenser, tube sockets (for tuning unit) and a calibrated 6" aerodiane dial with "Micromaster" mechanical bandspread. Set builders will find this an ideal set to install in their customers' expensive consoles. Uses 14 metal tubes: 3—6K7, 2—6J7, 2—6L7, 1—6B7, 1—6C5, 2—6H6, 2—6L6, 1—5Z3.
COMPLETE KIT OF PARTS
Includes punched and drilled black crackle-finished chassis base, all necessary condensers, resistors, switches, sockets, plugs, transformers and hardware. The only tools you need are a screw-driver, soldering iron and a pair of side-cutting pliers. Furnished with complete set of diagrams and detailed instructions. Less only tubes and speaker.
A10237. YOUR PRICE
$58.25
COIL AND VARIABLE CONDENSER KIT
Includes completely wired and aligned tuning units; Band switch; Calibrated 6" dial; Noise silencer I.F. coils; Beat-frequency Osc. coil; Matched pair of crystal filter trans.; Iron-core I.F. output and band expansion coils; 6 R.F. chokes; instruction sheets and diagrams.
A10238. YOUR PRICE
$29.40
A10236. Punched and drilled Black Crackle chassis base. Size 13"x17"x3". NET
$3.23
KNIGHT 12 INCH DYNAMIC SPEAKER
A 12" Knight speaker especially selected to work with above set. Will capably handle the output of the P. P. 6L6's. Equipped with 1250 ohm field coil, output transformer, cord and plug.
A10239. YOUR PRICE
$4.55

Fig. 18. 1937 "Build Your Own." Allied began using the phrase "Build Your Own" on its kit pages in 1937. Later it would use the phrase only for its own kit products. (Allied Radio Catalog, 1937)

company began using the phrase "Build Your Own" (complete with the quotation marks) on pages with kit products.[17]

The following year Allied followed up with five- and six-tube receivers, and a four-tube set it called the "Ocean Hopper." Hi-Fi amplifiers were soon to come. Also, there were kits from less familiar names, Tobe and Gen-Ral of Fig. 19, for example, in addition to a series of kits based on articles appearing in *Popular Mechanics* magazine, and using "Allied approved parts," of Fig. 20.[18] It is not clear how or if these kits were branded—whether they were sold under the Allied, Knight, or *Popular Mechanics* name. Over a couple of years, the series grew to more than a dozen kits, and then vanished.

In its 1938 catalog, Allied listed 23 of its Knight brand kits, and also sold schematics for them for five cents each.

Meissner, which had been slowly building out its line of kits, introduced the "Analyst" in 1939, shown in Fig. 21. The Analyst was actually several different instruments in a single package, including an "audio channel" for audio analysis and gain measurements, an audio generator, a radio frequency generator, a line current indicator for measuring power, and a DC voltmeter. The package used five 6E5 "magic eye" tubes, and must have looked pretty

Gen-Ral Super DX8 Professional
SHORT WAVE KIT
A completely engineered professional type 8 Tube Short Wave Superhet, ready for construction. Tunes 17 to 200 meters (1.5 to 18 megacycles) in 4 bands. Features continuous Bandspread Tuning, Beat Oscillator for C.W. reception, Tuned R.F. stage, stand-by switch, manual or Automatic Volume Control, latest tubes, pi-wound I.F.'s, optional Crystal Filter, etc. Uses 2—58, 1—2A7, 1—2A6, 1—2A5, 2—56, 1—80 tubes. The Coil Kit is completely assembled, wired and aligned. Bandspread Condenser Unit and Airplane Dial are assembled. Send for detailed Parts List and Wiring Diagram.
COMPLETE KIT OF PARTS
Consists of Foundation Unit including drilled chassis base and finished front panel; assembled 4 band Short Wave Coil and Switching unit; assembled 3 gang condenser and dial unit; transformers, condensers, resistors, sockets, hardware, instructions, diagrams, etc. Less speaker and tubes.
A10325. YOUR PRICE..... $32.75
A10321. FOUNDATION UNIT. Consists of drilled and punched chassis base, finished front panel and constructional data. NET..... $2.06
A10326. COIL AND CONDENSER KIT. Consists of assembled Gen-Ral 4 band short wave coil unit, with 2—I.F.'s, beat oscillator, and DeJong bandspread condenser. NET..... $18.25
A9598. Matched 8½" Dynamic speaker, with 4 ft. cord and plug. NET..... $3.10

Fig. 19. 1937 Gen-Ral receiver. The Super DX8 Professional was a complete short wave receiver kit. (Allied Radio Catalog, 1937)

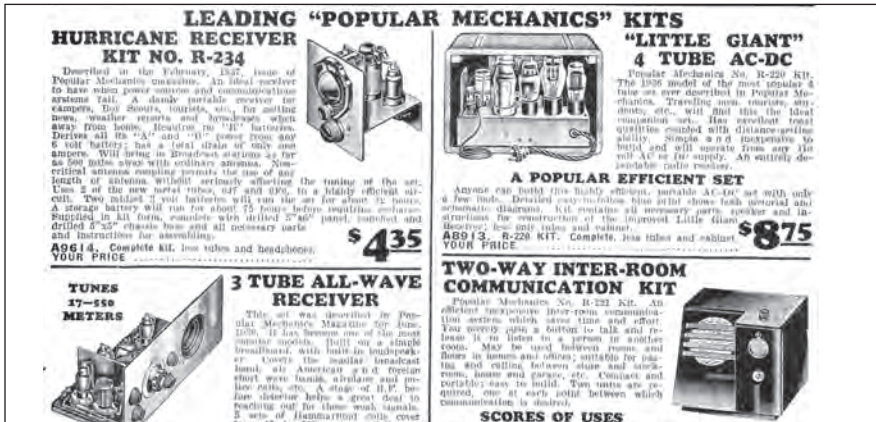

LEADING "POPULAR MECHANICS" KITS
HURRICANE RECEIVER KIT NO. R-234
Described in the February, 1937, issue of Popular Mechanics magazine. An ideal receiver to have when power service and communications systems fail. A dandy portable receiver for campers, for hours, tourists, etc., for sailing news, weather reports and broadcasts when away from home. Requires no "B" batteries. Derives all its "A" and "B" power from any 6 volt battery; has a total drain of only one ampere. Will bring in Broadcast stations as far as 500 miles away with ordinary antenna. Non-critical antenna coupling permits the use of any length of antenna. Without seriously affecting the tuning of the set. Uses 2 of the new metal tubes, 6J7 and 6F6, in a highly efficient circuit. Two added 7 volt batteries will run the set for about 32 hours. A storage battery will run for about 75 hours before requiring recharge. Supplied in kit form, consists with drilled 2"x6" panel, punched and drilled 5"x7" chassis base and all necessary parts and instructions for assembling.
A9614. Complete kit, less tubes and headphones. YOUR PRICE..... $4.35
"LITTLE GIANT" 4 TUBE AC-DC
A POPULAR EFFICIENT SET
A9613. R-220 KIT. Complete, less tubes and cabinet. YOUR PRICE..... $8.75
TUNES 17—550 METERS
3 TUBE ALL-WAVE RECEIVER
of Impedance-coupled audio. A convenient twin tip jack is incorporated so that either phones or speaker can be used. Low-loss coil forms and Isolantite sockets are used throughout. May be used with external A.C. power pack, or with "A" and "B" batteries, whichever is desired by the builder. Uses 1—6D6, 1—6C6 and 1—38 tubes. Comes complete with all necessary parts, including panel cut and drilled for speaker but less tubes. With coils.
A9615. Complete kit, less tubes and batteries..... $20.55
TWO-WAY INTER-ROOM COMMUNICATION KIT
SCORES OF USES
A8914. R-221 KIT for 1 unit only (2 required.) Complete, less tubes and cabinet. YOUR PRICE..... $9.10
A8923. Cabinet only, as shown in illustration. NET..... $2.45
A3502. 4 conductor connecting cable. Per 10 ft. 32c

Fig. 20. 1937 *Popular Mechanics* kit ads. Allied began selling kits based on construction articles appearing in *Popular Mechanics* magazine. The kits used "Allied approved parts." Whether or not Allied had struck some kind of deal with *Popular Mechanics* is not clear. (Allied Radio Catalog, 1937)

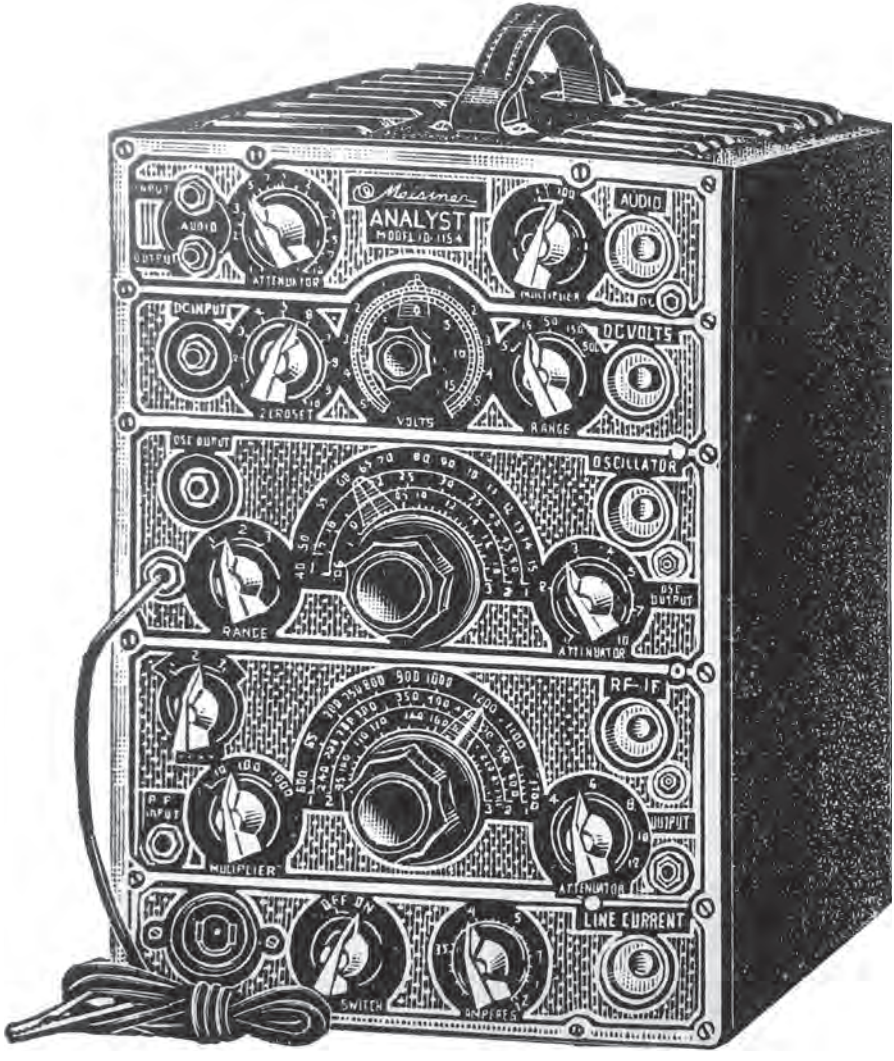


Fig. 21. 1939 Meissner Analyst. The Meissner Analyst, with its five glowing 6E5 "magic eye" tubes made a real statement on any test bench. (Radio's Master Catalog, 1939)

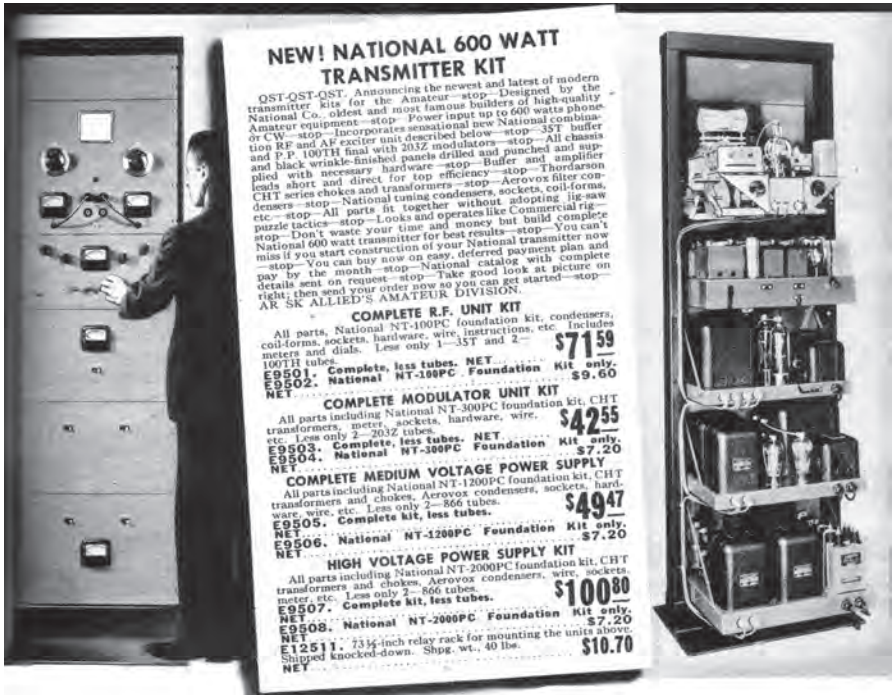
impressive on the bench. It was expensive—$60 without the tubes.[19]

Lest the reader get the impression that all kits from the early days were bread box-sized, consider National's 600 watt, 6 foot tall transmitter kit, released in 1939, shown in Fig. 22.[20]

It was possible to buy the entire package, or individual components including the RF deck, a modulator, the low voltage supply, the high voltage supply, and the rack. The entire thing, including the rack, came to $275 (about $5100, adjusted for inflation),

which sounds like a lot of money, except that it was also offered fully assembled for a little over $1700 (nearly $32,000, today).

Stancor, a leading manufacturer of transformers and chokes, released a series of amateur transmitters beginning in 1937, as shown in Fig. 23.[21] By 1942,



NEW! NATIONAL 600 WATT TRANSMITTER KIT

QST-QST-QST. Announcing the newest and latest of modern transmitter kits for the Amateur—stop—Designed by the National Co., oldest and most famous builders of high-quality Amateur equipment—stop—Power input up to 600 watts phone or CW—stop—Incorporates sensational new National combination RF and AF exciter unit described below—stop—35T buffer and P.P. 100TH final with 203Z modulators—stop—All chassis and black wrinkle-finished panels drilled and punched and supplied with necessary hardware—stop—Buffer and amplifier leads short and direct for top efficiency—stop—Thordarson CHT series chokes and transformers—stop—Aerovox filter condensers—stop—National tuning condensers, sockets, coil-forms, etc.—stop—All parts fit together without adopting jig-saw puzzle tactics—stop—Looks and operates like Commercial rig—stop—Don't waste your time and money but build complete National 600 watt transmitter for best results—stop—You can't miss if you start construction of your National transmitter now—stop—You can buy now on easy, deferred payment plan and pay by the month—stop—National catalog with complete details sent on request—stop—Take good look at picture on right; then send your order now so you can get started—stop—
AR SK ALLIED'S AMATEUR DIVISION.

COMPLETE R.F. UNIT KIT

All parts, National NT-100PC foundation kit, condensers, coil-forms, sockets, hardware, wire, instructions, etc. Includes meters and dials. Less only 1—35T and 2—100TH tubes.
E9501. Complete, less tubes. NET $71.59
E9502. National NT-100PC Foundation Kit only. NET $9.60

COMPLETE MODULATOR UNIT KIT

All parts including National NT-300PC foundation kit, CHT transformers, meter, sockets, hardware, wire, etc. Less only 2—203Z tubes.
E9503. Complete, less tubes. NET $42.55
E9504. National NT-300PC Foundation Kit only. NET $7.20

COMPLETE MEDIUM VOLTAGE POWER SUPPLY

All parts including National NT-1200PC foundation kit, CHT transformers and chokes, Aerovox condensers, sockets, hardware, wire, etc. Less only 2—866 tubes.
E9505. Complete kit, less tubes. NET $49.47
E9506. National NT-1200PC Foundation Kit only. NET $7.20

HIGH VOLTAGE POWER SUPPLY KIT

All parts including National NT-2000PC foundation kit, CHT transformers and chokes, Aerovox condensers, wire, sockets, meter, etc. Less only 2—866 tubes.
E9507. Complete kit, less tubes. NET $100.80
E9508. National NT-2000PC Foundation Kit only. NET $7.20
E12511. 7 3/4-inch relay rack for mounting the units above. Shipped knocked-down. Shpg. wt., 40 lbs. NET $10.70

Fig. 22. 1939 National transmitter. Before the 1950s, transmitters could be big and expensive. National's kit-form 600 watt unit stood more than 6 feet tall. It used a 100TH final and 203Z modulators. (Radio's Master Catalog, 1939)

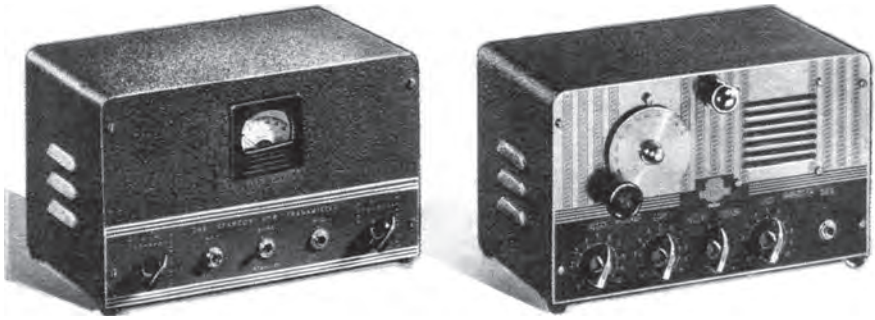


Fig. 23. 1939 Stancor transmitter (left) and transceiver. The Stancor model 10-P transmitter, 1938, and 112-T transceiver, 1940. Stancor is better known for its line of transformers and chokes, but the company made a number of kit-form products beginning in the late 30s. (Radio's Master Catalog, 1939)

the company had produced at least 40 transmitters, about half of them in kit form. The company's last amateur radio kits, the model 203-A and 203-W transmitters, were released in 1952.

In 1940, Allied changed its use of the "Build Your Own" slogan to emphasize the Knight brand.[22] The catalog page header now read "Knight 'Build Your Own' Kits," as in Fig. 24.

KNIGHT "Build Your Own" KITS
NEW KNIGHT AC-DC "OCEAN HOPPER"
An extremely efficient, easy-to-build receiver of modern design. Appropriately named "Ocean Hopper" because its possibilities are almost unlimited for far-reaching reception. One of the most successful "Knight" kits. Equipped with modern up-to-date tubes. Uses two new single-ended miniature tubes, 1—12SJ7-GT High-Gain R.F. pentode in a cathode-feed regenerative circuit and 1—70L7-GT Beam Power output and diode rectifier combined. Features a vernier tuning dial; shielded chassis construction; regeneration control. Has built-in power supply for AC or DC, 115 V. operation. Kit contains drilled metal chassis base and panel, sockets, condensers, resistors, wiring diagram, etc. Coils, tubes, speaker and headphones are extra—see below for listing. Shpg. wt., 8 lbs.
A9800. Complete Kit of Parts. YOUR PRICE $5.95
A9802. Tube Kit. Consists of 1—12SJ7GT and 1—70L7GT. NET $1.40
A9845. Coil Kit. Set of 4 coils for kit above. Tune 10 to 195 meters. $1.25
A5690. Broadcast Coil Kit. 2 coils cover range from 190 to 550 meters. NET 65c
A9801. 5" P.M. Speaker and transformer for use with above kit. NET $1.78
A wide range of new easy-to-build kits for the beginner as well as for the advanced experimenter. All KNIGHT kits can be assembled in a minimum amount of time. Chassis bases are punched and drilled; only the simplest tools are required for assembly. Even the radio novice can build these sets successfully. We can also supply matched parts lists for any set featured in construction articles in any radio publication.
BUILDER'S HANDBOOK
Allied's RADIO BUILDER'S HANDBOOK
A useful new manual prepared by ALLIED's engineers to aid the experimenter and builder. Tells how to select suitable circuits, read diagrams, layout and punch chassis bases and panels, correctly place and wire radio parts, and efficiently operate radio receivers and transmitters. Includes socket lay-out information, coil-winding data, and other valuable charts. Shows schematic and pictorial diagrams of beginner and advanced sets, transmitters, fence controls, photo-electric relays, etc. 8½x11". Shpg. wt., 2 lbs.
A1753. NET 10c
"BUILD-YOUR-OWN" WIRING DIAGRAMS
Clear, easy-to-read diagrams with complete matched parts lists. Enables you to build your own receivers, transmitters, amplifiers, power supplies and gadgets, using the latest type tubes and modern efficient circuits. Carefully designed for efficiency.
A1790. 1 Tube "Short Wave" Set.
A1758. 2 Tube DX or S.W. Battery Set.
A1791. 2 Tube "Ocean Hopper."
A1760. 4 Tube A.C. Broadcast TRF.
A1761. 4 Tube A.C.-D.C. Broadcast TRF.
A1762. 4 Metal Tube "Super-Gainer."
A1776. 4 Tube 1.4 Volt Portable.
A1766. 5 Tube Skip-Band A.C. Super.
A1765. 5 Tube A.C. Broadcast TRF.
A1794. 5 Tube A.C. Broadcast Super.
A1781. 6 Tube 6 Volt Skip Band Super.
A1792. 6 Tube B.C. and S.W. Set.
A1767. 6 Tube All-Wave Super.
A1781. 6 Tube 6 Volt Skip Band Super.
A4442. Experimenters' Kit and 1 Tube Set.
A4443. Beat Oscillator Kit.
A4444. Wireless Photo Oscillator.
A4445. Tuo Knight 4 T AC-DC T.R.F.
A4446. 1 Tube Pocket Set.
A4449. Junior Receiver-Transmitter.
A1777. 2½ Meter Transceiver.
A4448. 20 Watt Transmitter.
A1789. Volume Expander for Radio or P.A.
A1770. Crystal Set.
A1793. 4 Watt AC-DC Amplifier.
A1771. 4 Watt Amplifier and Power Supply.
A1775. 1 Tube Phono-Amplifier.
A1772. 3 Tube 2 Band A.C.-D.C. TRF.
A1773. 3 Tube 2 Band 1 A.C. Super.
A1774. 8 Tube Ham Super.
A1752. Photo-Electric Coil Unit.
A1778. Noise Silencer.
A1782. Coil Winding Data.
YOUR PRICE EACH DIAGRAM (To cover handling and mailing) 5c
Choice Of Any 6 Diagrams 20c
Schools—colleges—radio clubs. Write for our attractive quantity prices for wiring diagrams.
1940 2-TUBE DX-ER KIT
The very newest version of the most popular low-priced kit for the short-wave beginner, experimenter, and radio student. Uses two economical 1.4 volt tubes 1F5G and 1N5G in this advanced circuit employing high-gain regenerative detector and resistance-coupled audio. With "on-off" switch. Operates from a single dry cell and two "B" batteries. Kit contains all parts, including drilled panel and baseboard. Coils and accessories listed below are extra. 6 lbs.
A9880. NET $3.25
A9881. Tube and Battery Kit. 1-1F5G and 1-1N5G tubes, 1-1½ volt dry cell, and 2-45 volt "B" batteries. Shpg. wt., 20 lbs. NET $3.37
A2908. Brandes 2400 ohm headphones. NET $1.79
A5565. Coil Kit. Set of four coils covering 9.5 to 21 meters. Wt., 2 lbs. NET 85c
A5566. Coil Kit. Set of 2 coils covering 190-550 meters. Wt., 1 lb. NET 65c
AUDIO AMPLIFIER KIT
A9840. For use with 2-Tube DX-ER. Uses a type 33 tube (not supplied). Will operate small magnetic speaker. Includes all parts required. Shpg. wt., 3 lbs. NET $1.15
A9841. Tube and Battery Kit for Audio Amplifier. Contains 1-33 tube, 1-22½ volt "C" and 1-45 volt "B" battery. Shpg. Wt., 13 lbs. NET $2.25
4-TUBE 1½ VOLT PORTABLE KIT
Now you can build your own Portable Battery Radio using the economical 1.4 volt tubes. Here's a set you can carry and play anywhere. Loop-type aerial is built into carrying case; no ground wire is needed. Employs four low-drain 1.4 tubes in an efficient Superhet circuit: 1-1A7G, 1-1N5G, 1-1H5G, 1-1C5G. Operates from economical "AB" Power Pack; "A" drain only 25 amps., "B" drain only 30 M.A. Tunes standard broadcast band. Features include A.V.C. and full 5" P.M. speaker. Beautiful new luggage-type carrying case, with lid covers and handle. Size: 9"x9"x7". Complete kit includes drilled chassis base, speaker, carrying case, diagrams, and all parts, except tubes and power pack. Shpg. wt., 7 lbs.
A9870. Complete Parts Kit, including Carrying Case. NET $9.25
A9871. Tube Kit. Includes 1-1A7G, 1-1N5G, 1-1H5G, 1-1C5G. NET $2.70
A10001. Burgess 150 hour "AB" Power Pack. Wt., 5 lbs. NET $2.36
KNIGHT 5-TUBE SUPER KIT
A modern, highly efficient superhet receiver covering from 1700 K.C. to 550 K.C. This includes the standard broadcast band and some of the police bands. Push-buttons, conveniently located at top of set, enable you to automatically select 4 of your favorite stations. This does not interfere with the manual tuning of the receiver. Push-buttons are easily and quickly set by hand. No tools are required. Has attractive-looking slide-rule dial. A tone control is provided for emphasizing the bass response. Has dynamic speaker. Uses 1—6A8G, 1—6K7, 1—6Q7G, 1—2SL6G, and 1—2S2G6 tubes. Kit is supplied with drilled chassis, condensers, resistors, sockets, etc. Size of chassis is 11"x5¾"x1¾". For 115 V., 60 cycles A.C. Shpg. wt., 10 lbs.
A9825. Complete Parts Kit. Less tubes and cabinet. NET $5.95
A9826. Tube Kit. 1—6A8G, 1—6K7, 1—6Q7G, 1—2SL6G, and 1—2S2G6 tubes. NET $2.45
A9827. Wood Cabinet for above. 13½"x8"x9½". Wt., 4 lbs. NET $1.49
6-TUBE BROADCAST & S.W. KIT
An extremely efficient 6-tube broadcast and short-wave receiver. Provides a high degree of selectivity and sensitivity. The push-pull audio amplifier delivers plenty of power for speaker or phones. Uses plug-in coils for complete coverage. Supplied with 1—A17, 2—75, 2—43, 1—2S2S tubes, punched and drilled chassis, condensers, diagrams, etc. Coils not supplied. See below. For 115 V. A.C. or D.C. Shpg. wt., 9 lbs.
A9803. Complete Kit of Parts. NET $9.75
A9804. S.W. Coil Kit. 4 coils tuning from 16 to 195 meters. NET $1.85
A9805. B.C. Coils. 2 coils tuning from 190 to 550 meters. NET 85c
A9801. 5" P.M. speaker and transformer for use with above kit. NET $1.78
1-TUBE PHONO-AMPLIFIER KIT
An efficiently engineered kit designed for excellent reproduction of all phonograph records when used with any high-impedance magnetic or crystal pickup and modern 2-tube unit. Operates from A.C. or D.C. Includes 5" P.M. speaker. Employs new 70L7GT tube, a dual-purpose rectifier and Beam Power amplifier. Tone is exceptionally fine. Has volume control. Kit includes punched and drilled chassis base and all necessary parts (less tube). Wt., 7 lbs.
A9882. Kit as described. NET $4.75
A907. Raytheon 70L7GT tube. 86c
"TINY KNIGHT" 4-TUBE A.C.-D.C. TRF KIT
Here is a kit for an extremely compact, sensitive set. Uses high-gain coils tuning from 175 to 360 meters. Circuit design and chassis layout result in very high-regenerative action for maximum sensitivity and selectivity. Has a 2 gang condenser, volume control and switch, and built-in wire antenna. Supplies complete less only tubes and cabinet. Includes a punched and drilled chassis base. Shpg. wt., 3 lbs.
A9588. NET $4.75
A9589. Plastic walnut finish cabinet. Size 7"x5¼"x4½". Wt., 1 lb. NET 79c
A9587. Tube Kit. 6K7GT, 6Q7GT, 25L6GT and 25Z6GT tubes. NET $2.50
134 OUR PRICES ARE ALWAYS LOWER—WE WILL NOT BE UNDERSOLD

Fig. 24. 1940 Knight "Build Your Own" kits ad. (Allied Radio Catalog, 1940, p. 134)

Milestone 1941: The United States enters World War II. Amateur radio goes silent.

In 1941 the United States was finally drawn into World War II. Allied's 1943 catalog shrank in response to wartime shortages and restrictions placed on amateur radio.[23] The major manufacturers reduced their presence in the catalog, and Allied pulled all of its regular kits, replacing them with "training kits" for the military in general, and for the signal corps in particular, though anyone could purchase the kits shown in Fig. 25.

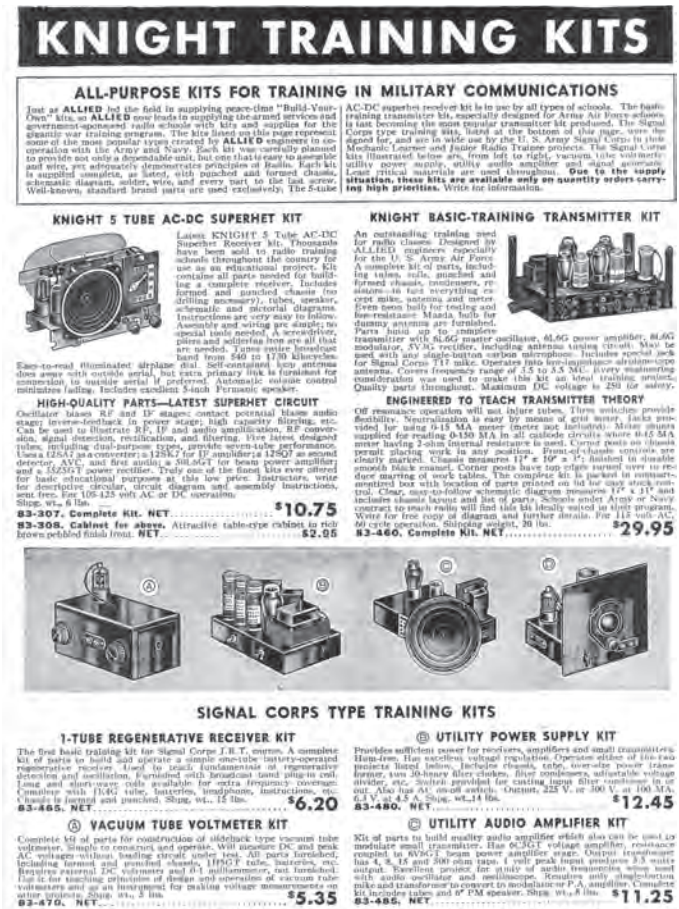

KNIGHT TRAINING KITS
ALL-PURPOSE KITS FOR TRAINING IN MILITARY COMMUNICATIONS
KNIGHT 5 TUBE AC-DC SUPERHET KIT
KNIGHT BASIC-TRAINING TRANSMITTER KIT
HIGH-QUALITY PARTS—LATEST SUPERHET CIRCUIT
ENGINEERED TO TEACH TRANSMITTER THEORY
SIGNAL CORPS TYPE TRAINING KITS
1-TUBE REGENERATIVE RECEIVER KIT
UTILITY POWER SUPPLY KIT
VACUUM TUBE VOLTMETER KIT
UTILITY AUDIO AMPLIFIER KIT
FIELD STRENGTH METER KIT
SIGNAL GENERATOR KIT
60
LOWEST PRICES—HIGHEST QUALITY—BEST SERVICE

Fig. 25. 1943 Training kits from Knight. How much business Allied actually did with the government is unknown. The company did not publish a catalog in 1944 or 1945. (Allied Radio Catalog, 1943, p. 60)

Milestone 1945: World War II ends in August.

Milestone 1945: Amateur radio 10 meter band reopens in November.

Milestone 1946: 80, 40, and 20 meter bands reopen.

WRL's Globe Trotter may have been the first post-war transmitter kit on the market.[24] A receiver was also offered in a smaller picture. Both are shown in Fig. 26.

New! Exclusive! Ready Now!
WRL
Globe Trotter
40 WATTS INPUT
TRANSMITTER
KIT
The Sensation of the Year!
Transmitter kits are almost impossible to get, but Leo, W9GFQ, now offers amateurs the new WRL Globe-Trotter, destined to become one of the most popular kits on the market. The WRL Globe-Trotter is capable of 40 watts input on C.W. and 25 watts input on phone on all bands from 1500 KC through 28 Megacycles. Incorporates the proven Tritet Oscillator using a 20 meter X—Tal and providing sufficient drive at 10 meters for the 807 final. Heising choke modulation is incorporated and gives excellent results and good tonal quality. Look this over! It has everything! Three bands are all pretuned and available at the turn of a switch, 10, 20, and 80 meters. Metering is provided for both oscillator and final stages. The transmitter uses two power supplies, one furnishing power to the 807 final and modulator tubes, and the other supplying the speech, amplifier and oscillator stage. Tube Line Up: RF—6L6 OSC. 807 final amplifier; Audio—6SJ7, 6N7, 2-6V6GS—Rectifiers, 2-5U4G.
Complete kit including all parts, chassis, panel, streamlined cabinet less tubes, coils and meters.
$59.95
Cat. No. 70-300
Kit Same as above. Wired by our engineers
Cat. No. 70-312.....$75.00
ACCESSORIES
Complete kit of 8 Tubes
Cat. No. 70-314..... $5.95
3 in. Meter Cat. No. 70-316..... 4.95
Coils per set (any band)
Cat. No. 70-316..... 2.95
Crystals-40-80 Meters Mts.
Cat. No. 70-322..... ea. 2.65
Quality Crystal Mike and Stand
Cat. No. 70-320..... 9.45
NEW
BC 348Q
RECEIVERS
Original government price over $200.
$85.00
Including steel case, Speaker furnished at small added cost.
Cat. No. 35-61.
Here is one of the hottest war-surplus receivers that will be available. 9 tubes, 2 tuned RF stages, 3 stages of IF amplification. Frequency range, 200 to 500 kilocycles; 1½ to 18 MC in four bands. Tunes weather and aircraft bands, and all ham bands except 10 meters. Ask about our special converter for 10 meter operation.
BC-610 (Hallicrafters HT-4E) TRANSMITTERS
Counterpart of the famous SCR-299. 825 watts input on CW, 540 watts input on phone; 3 sets of coils. Range of 1½ to 18 Meg. Completely reconditioned, Cat. No. R70-202, $510.00—New Cat. No. 70-202, $760.00. Reconditioned or new sets converted to 10 meters, $25 extra.
Giant Radio Reference Map with time and amateur zones, standard and short wave stations, and other valuable information. Printed in colors. Size 31½x48½ inches.....Only 15¢
Write for our latest flyer of radio parts. FREE
World Radio
LABORATORIES
EVERYTHING IN RADIO
INCORPORATED
Formerly Wholesale Radio Laboratories
Address Dept. RN-7. Council Bluffs. Iowa

Fig. 26. 1946 WRL transmitter kit. The tubes, coils, crystals, microphone, and meter were sold separately—a once-common practice that would quickly become a thing of the past. (*Radio News*, July 1946)

Atomic Heater and Radio Corporation certainly was a catchy name right after World War II.[25] They offered a six-tube superhet kit receiver that covered the broadcast band, shown in Fig. 27.

Dealers WHY WAIT FOR YOUR RADIO?
"BUILD YOUR OWN"
ATOMIC HEATER & RADIO CORP.
PROUDLY PRESENTS
The Finest in Radio Kits
A COMPLETE 6 TUBE SUPERHET.
COVERS THE BROADCAST BAND FROM
550-1700 KC.
This set has been fully engineered and designed to make construction simple. All parts mounted, cabinet included.
Tubes required—two 12SK7, one 12SA7, one 12SQ7, one 35L6, one 50L6 and one 35Z5.
Your cost $15.80 without tubes. Terms 10% deposit with order, balance C.O.D.
IMMEDIATE DELIVERY
ATOMIC HEATER
& RADIO CORPORATION
Dept. A
104 PARK ROW, NEW YORK 7, N. Y.

Fig. 27. 1946 Atomic Heater broadcast band radio receiver. Maybe the best name ever for a radio company. (*Radio News*, May 1946)

Turning Point: 1947

During WWII, kits mostly vanished from publications like *Radio News*, as the war effort began to consume large quantities of parts, supplies, and raw materials that previously had been plentiful, and most electronics manufacturers essentially went to work for the government. When the war ended in August 1945, Allied picked up where it left off with kits, and kits also began to filter back into the pages of popular magazines.

The year 1947 is notable in several important ways. First, early in 1946, the first trickles of war surplus electronics began to drip into magazine advertising. By early 1947, the floodgates were wide open. Full page ads began to appear from companies jumping into the war surplus market, shown in Fig. 28.[26] In its own way, war surplus would set off a kind of gold rush. Heath, for one, was quick to capitalize on this tsunami of parts and equipment.

Second, 1947 is important because it is the delineator with which discussions of electronic kits can be broken down into two basic parts: "before Heath," and "after Heath." Heath placed its first ad in the July issue of *Radio News.* The ad listed a variety of discrete surplus components—and its first kit product, the O-1 oscilloscope, made largely from surplus parts. A picture of the O-1 scope is shown in Fig. 29.

WAR SURPLUS EQUIPMENT!
At A Fraction of Their Original Government Cost!
SUN RADIO.....The Home Of Nationally Known Radio Parts
SUN'S GREATEST OFFERS
While They Last!
CHECK THESE VALUES!
WALKIE TALKIES
SCR195 Walkie Talkies, brand new, weight 27½ pounds including knapsack. Range up to 25 miles in open country. Frequency 52.8 to 65.8 MC. Transmitter and receiver with regular hand set. Complete ready to operate with spare parts.
Exc's
$69.95
Set....$129.90
INTERPHONE AMPLIFIER
COMPLETE 4 TUBE
Comes in an aluminum cabinet 9 ¾x 4 ¾x3 ½ inches with two 12J5GT tubes and two 12A6; also General Electric Dynamotor 28DC Volt input and 250 VDC output at 60 MA. Complete instructions and diagram for high fidelity phonograph or speech for 110 Volt operation. This is the greatest offering made in War Surplus Electronics. Yours for only $8.95
SPERRY AMPLIFIER
Brand new servo amplifier containing two beam power output tubes (1632) similar to 25L6, two twin triodes (1633 and 1634) similar to 6SC7, two mica condensers, dozens of color coded half watt resistors, two dual and four section bathtub condensers, three transformers, two wafer switches, one volume control, four octal sockets. Easily convertible $3.95
BC-684 F.M. 35 WATT TRANSMITTER
Brand new, complete with eight tubes; crystal control, 10 channel push-button non-tenier modulation cal'... less cover-plate, crystal and power supply..... $17.95
RHOMBIC RECEIVING ANTENNA
Complete with all accessories including 2200 feet of No. 14 copper weld wire, 50 feet of heavy twin X lead 72 ohm good up to 2 kw, dozens of insulators, pulleys, neon lightning arresters, ground rods and everything to erect, less poles... $24.95
NAVY SPEAKER
Stromberg Carlson and RCA waterproof speakers. Brand new in original cartons. 25 Watt PM driver unit with line matching transformer and projector mounted in heavy duty round metal baffle. Ideal for communication receivers and sound systems at lowest price ever offered..... $14.95
D.C. Milliammeter
Brand new General Electric 2" round panel meters 0-300.. $2.97
Portable 2-Band Receiver
Built to rigid specifications of armed forces. 5-tube superhet covering std. bdcst. and 5.8-18.3 mc shortwave. High sensitivity proved by war use overseas. Complete with longlife 91 ½V pack and instruction-maintenance manual. Brand new in sealed cartons..... $29.95
Above set also available with built-in whip antenna for added sensitivity..... $34.95
100 WATT BENDIX Transmitter TA12-B
$49.95
CHECK THESE VALUES . . . Three 807 tubes. Four 12SK7 11. One 2-inch S-amp. RF meter. Four separate Master Oscillators. (These can be easily changed to cover 20-40-80 meters and by using crystal for the 13 mater band you will have a complete coverage transmitter.)
Four separate output tanks . . . One 4-position selector channel switch having seven sections which changes the ECO, IPA and output tanks simultaneously. All the controls are mounted on the front panel. The housing is cast aluminum; shields and case are sheet aluminum. Dimensions 11x12x15 inches; weight 35 ½ lbs. Complete, simple instructions for conversion furnished. Complete with tubes..... $49.95
SUPERHETERODYNE RECEIVER
This crystal fixed frequency receiver comes with full conversion instructions for variable tuning of all ham bands and broadcast. A highly selective superheterodyne receiver, 110 V. A.C. power supply built in. Uses the following tubes: 6K7 RF Amplifier; 6K8 Mixer and Oscillator; 6K7 I.F. Amplifier, 6F7 Detector and A.V.C.; 6C8 Output and Noise Suppressor; 80 Rectifier. Dimensions: 3 ½x19x11 ½ inches. Comes complete brand new, with one set of coils and two sets of tubes..... $16.95
xtra set of coils..... $2.95
PORTABLE AMPLIFYING MEGAPHONE
S. Army Signal Corps Surplus! Complete in portable carrying case with electric megaphone and microphone, pistol grip and trigger switch. Additional hand microphone and switch. Portable tripod stand. Combination amplifier and battery case. Projects voice up to ¾ mile..... $59.95
OHM METER
Weston No. 689
A beautiful instrument for accurate work. Scale 0-10 ohm and 0-1000 ohm scaled to read 1/20 on an ohm with ease. This 2 ½" round meter is housed in a black bakelite case 1 ¾"x2 ¾"x 3". Complete with heavy duty felt-lined leather case and lock. Special $14.95
All Items F.O.B. Washington, D. C. Orders $30.00 or Less, Cash with Order. Above $30.00 25% with Order. Balance C.O.D.
SUN RADIO
OF WASHINGTON, D. C.
938 F STREET, N. W. WASH. 4, D. C.

Fig. 28. 1947 war surplus equipment. After World War II, government surplus electronics began flooding onto the market. Numerous companies, large and small, started cashing in. (*Radio News*, July 1947)

Fig. 29. Heath O-1 oscilloscope. Heath's first kit product, the O-1 oscilloscope, was introduced in August 1947. (Erich Brueschke collection)

Milestone 1947: The first Heath kit, the O-1 oscilloscope.

Milestone 1947: Bell Labs invents the transistor.

And third, 1947 was the beginning of what W. Walter Watts, group executive vice president of Radio Corporation of America (RCA), called "the revolution in electronics and electronic components." In 1946, virtually the entire output of the country's electronic components

industry was consumed by the radio and (fledgling) television industry. By 1947, development of computers, factory automation systems, post-war military defense projects in general, and large scale development of missiles in particular, combined with the development of entirely new devices—most notably the transistor—to fundamentally remake the electronics industry.

The components industry, worth about $300 million in 1946 would, in just over a decade, grow to nearly $3 billion. The new parts consumers included industrial giants like aircraft manufacturers and defense contractors Lockheed and Boeing, and computer makers like IBM, Univac, and Burroughs, to name only a few.

In many, perhaps most, cases, the parts were supplied not by huge companies, but by hundreds and hundreds of small ones. The flow of cash, then, was both deep and wide. It was a rising tide of money that lifted all boats, including just about any and every electronics company you can name. The current swept Heath, and other kit makers, along. One small company was General Electronic[27] (not to be confused with General Electric), which made a small and handy VOM kit at $9.50, shown in Fig. 30.

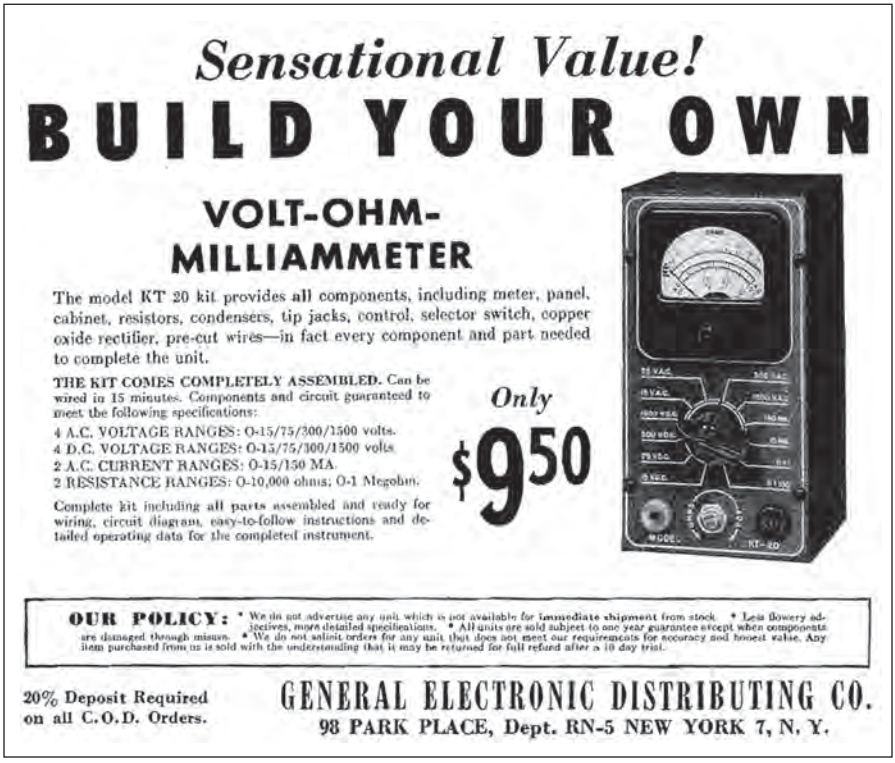

Sensational Value!
BUILD YOUR OWN
VOLT-OHM-MILLIAMMETER
The model KT 20 kit provides all components, including meter, panel, cabinet, resistors, condensers, tip jacks, control, selector switch, copper oxide rectifier, pre-cut wires—in fact every component and part needed to complete the unit.
THE KIT COMES COMPLETELY ASSEMBLED. Can be wired in 15 minutes. Components and circuit guaranteed to meet the following specifications:
4 A.C. VOLTAGE RANGES: 0-15/75/300/1500 volts.
4 D.C. VOLTAGE RANGES: 0-15/75/300/1500 volts
2 A.C. CURRENT RANGES: 0-15/150 MA.
2 RESISTANCE RANGES: 0-10,000 ohms; 0-1 Megohm.
Complete kit including all parts assembled and ready for wiring, circuit diagram, easy-to-follow instructions and detailed operating data for the completed instrument.
Only
$9.50
KT-20
OUR POLICY: * We do not advertise any unit which is not available for immediate shipment from stock. * Less Bowery advertises, more detailed specifications. * All units are sold subject to one year guarantee except when components are damaged through misuse. * We do not solicit orders for any unit that does not meet our requirements for accuracy and honest value. Any item purchased from us is sold with the understanding that it may be returned for full refund after a 10 day trial.
20% Deposit Required on all C.O.D. Orders.
GENERAL ELECTRONIC DISTRIBUTING CO.
98 PARK PLACE, Dept. RN-5 NEW YORK 7, N. Y.

Fig. 30. 1947 General Electronic VOM. The VOM was a staple of kit products, and over time they became smaller and less expensive. (*Radio News*, July 1947)

EICO

The Electronic Instruments Company (EICO) was founded in New York (Brooklyn, to be exact) in 1945. EICO would grow to become Heath's most serious competition, but it did not originally make kits. Initially, EICO made fully assembled test equipment.

EICO's first ad in *Radio News* predates Heath's first ad by exactly a year. The company's ad in July 1946 featured only one product. The unit had no model number. EICO called it an electron tracer, shown in Fig. 31. It would eventually be given a model number (113) and be called the MultiAnalyst, a combination signal tracer and vacuum tube voltmeter (VTVM). The unit was fully assembled and sold for $89.50.[28]

Things may have been touch and go for a while at EICO. The company advertised only twice in 1947, and only sporadically though 1948.

EICO's first kit was actually its sixth product, the model 221 VTVM, advertised in August 1948.

EICO used a different business model than Heath. While Heath sold directly through its catalog, EICO sold its products through local radio shops all over the country. An advantage of this method was that the potential customer could go to a store and actually try out (or at least handle) the instrument before purchasing.

By the end of 1948, a virtual tidal wave of war surplus gushed out of the pages of magazines like *Radio News*. Page after page featured ads from companies large and small, all selling surplus electronics.

ELECTRON TRACER
• A VACUUM TUBE VOLTMETER
• AN AUDIBLE SIGNAL TRACER
• AN ELECTRONIC OHMMETER
A Complete 6 Tube Service Laboratory
RANGES:
DC Volts: 5/10/100/500/1000; + or —3%.
DC Input resistance: 26 megohms
AC Volts: 5/10/100/500/1000.
AC Input resistance: Over .5 megohms.
OHMMETER: From .2 ohm to 1000 megohms.
See your local jobber. If he does not carry the ELECTRON TRACER, write us.
$89.50 NET
ELECTRONIC INSTRUMENT CO., Inc.
926 CLARKSON AVENUE BROOKLYN 3, N. Y.

Fig. 31. 1946 EICO VTVM. EICO's first ad was for a fully assembled product—the "electron tracer." Kits would come a couple of years later. (*Radio News*, July 1946)

And between the end of the war and 1950, many familiar names like Walter Ashe, Lafayette, Burnstein-Applebee, Fair Radio Sales, McGee Radio Supply, Newark Radio, and others had become well-established.

During this same time, numerous small companies dabbled in kits, including kits for the new medium of television.

By 1948, television was becoming a big deal; see the Transvision ad in Fig. 32.[29] A number of companies introduced kit-form TV products. "Dabbled" is the operative word, as many companies disappeared quickly.

The capacitor making company Micamold built one amateur radio kit transmitter,[30] shown in Fig. 33.

EICO released its first kit product shown in Fig. 34 in August 1948, perhaps inspired by Heath's success.[31] Heath's VTVM had been introduced about 10 months earlier.

In December 1948, Heath bought four full pages in *Radio News*, featuring ten kits and two pages of surplus.

Then, in 1949, the E. F. Johnson company raised the bar for kit-form amateur radio equipment with the Viking I transmitter of Fig. 35, for $209.50. It was instantly successful. Heath could not have failed to notice, but the company wasn't ready to go there quite yet. And that same year, Eldico introduced the kit-form TR-75 transmitter, and in 1950, Eldico introduced the EE-1[32] electronic keyer—the

TRANSVISION
New TV KITS and CABINETS
STANDARD and CUSTOM-TYPE MODELS at LOW COST
NEWEST in TELEVISION DESIGN • BIGGEST IN VALUE
Featuring
• PICTURES UP TO 150 SQ. INCHES
• CONTINUOUS TUNING ON ALL 12 CHANNELS
• LONG-RANGE RECEPTION
Model 10A TV Kit
New 10" TV KIT
at amazingly low price!
The new Transvision Model 10A electromagnetic TV Kit gives a bright, stable 52 sq. in. picture. Has 10" picture tube, and CONTINUOUS TUNING UNIT (shown on the right hand page) on all 12 channels. Its high sensitivity makes for improved long-distance reception; especially good on high channels. Complete with all-channel double-folded dipole antenna and 60 ft. of lead-in wire.
MODEL 10A TV KIT, less cabinet ..... Net $199.00
MODEL 12A TV KIT, same as above, but has a 12" picture tube ..... Net 263.00
◀ NEW STREAMLINED CABINETS for Transvision Model 10A or 12A TV Kit. Made of select grain walnut with beautiful rubbed finish. Fully drilled, ready for installation of assembled receiver.
Walnut Cabinet for 10A or 12A (Specify) ..... Net $44.95
Mahogany and Blonde slightly higher.
New streamlined cabinets for Models 10A or 12A TV Kits, designed by Hal Bergstrom.
New 150 Sq. In. TV Kit
Model 10CL, with Roto-Table
This new Model 10CL is a 10" electromagnetic TV Kit, equipped with an all-angle lens (with color kit) giving a picture of 150 sq. in. The image is clearly visible from a very wide angle of vision, because of this specially designed lens. Also has the new CONTINUOUS TUNING UNIT shown on the right. This kit comes COMPLETE with CABINET, LENS, and ROTO-TABLE; also double-folded dipole antenna (all channel) and 60 ft. of lead-in wire.
MODEL 10CL TV Kit ..... Net $299.00
EASY TO ASSEMBLE . . . NO TECHNICAL KNOWLEDGE REQUIRED
Transvision's simple step-by-step Instruction Sheet makes assembling a TV Kit a pleasure. Each kit comes complete with all-channel double-folded dipole antenna and 60 ft. of lead-in wire. Nothing else to buy!

Fig. 32. 1948 Transvision TV. This Transvision ad assured the reader that its step-by-step instructions made its televisions easy to assemble, and that no technical knowledge was required. Transvision continued in business into the early 1960s. (*Radio and Television News*, December 1948, p. 100)

It's Front-page News!
MICAMOLD XTR-1
45 WATT - 3 BAND CW TRANSMITTER KIT
Only $34.
less tubes, crystal and key
Micamold fires the opening shot in the war on high prices with a low priced, high quality transmitter kit priced within easy reach of every amateur. Very simple to assemble. Complete from power supply to antenna matching network. Just plug in the tubes, crystal and key and you're on the air.
Operates on 80, 40 and 20 meters
Quality Engineered and Equipped Throughout
BAND SWITCHING . . . No coils to plug in. A flip of the switch puts you on 3.5, 7 or 14 MC band using suitable crystal.
SUREFIRE CIRCUIT . . . Crystal ECO (6AG7) driving final amplifier. No neutralization is required. Crystal current is less than one milliampere. Band switch controls both a tapped broad tuned oscillator plate coil and the final output circuit. Pi-network matches any antenna. Puts out a clean cut signal, no chirps.
ABSOLUTE SAFETY . . . No exposed live parts. When used with insulated lead-in wire it is impossible to get a shock during adjustment or operation.
SOUNDLY ENGINEERED . . . Designed to last and fully guaranteed! Every Micamold XTR-1 kit contains Grade A components including Micamold Capacitors, and is sold under the provisions of the standard warranty of the Radio Manufacturers Association. Simple, clear instructions for assembly, wiring and operation.
If your dealer does not have a kit on hand write to us for the name of the nearest dealer or send your order direct to Micamold with your remittance. Your kit will be shipped promptly.
Micamold
MICAMOLD RADIO CORPORATION
Manufacturers of High Quality Electrolytic, Paper, Mica Capacitors and Resistors
1087 FLUSHING AVENUE, BROOKLYN 6, N. Y.

Fig. 33. 1948 Micamold transmitter. Micamold, better known for making capacitors, introduced the XTR-1 in 1948—arguably one of the more obscure post-war amateur radio kits—the only kit product the company made. (*CQ*, April 1948)

NOW YOU CAN BUILD YOUR OWN
High Precision Vacuum Tube Voltmeter
For Only
EICO
$23.95!
The well known EICO Model 221K VTVM is now available in kit form with 7 easy to read diagrams. Includes all components. Nothing else to buy!
Model 221K VTVM kit enables you to build a superlative VTVM with all these features:
high input impedance—25 megohms
15 different ranges—ohms, AC and DC volts
double triode balanced bridge circuit—extremely stable
extra heavy duty AC isolation transformer
linear—2% overall accuracy
1000 megohm useful ohmmeter range
rugged huge 4½" meter movement—AC and DC on 1 scale—easy to read
sturdy steel case, portable—genuine leather removable handle
electronic AC range to 30 kc.
meter burnout impossible
individually calibrated scales
etched panel—scales cannot rub off
includes probes for testing to 30kc
Model 221K VTVM Kit with complete set of 7 stage-by-stage wiring and assembly diagrams, and full simple instructions, now at this amazingly low net price $23.95
Model P-75 High-Frequency Probe for above permits visual signal tracing to 100 Mc. ..... net $7.50
Complete Factory Wired VTVM Model 221
Contains all features listed in the above kit. Completely assembled, tested, ready to operate. $49.95
Write for literature on our line of High Precision, Economy priced test equipment.
EICO
If Your Jobber Is Out of Stock, Order Directly from Us, Mentioning His Name
ELECTRONIC INSTRUMENT CO., Inc.
377 BLAKE AVENUE
BROOKLYN 12, N. Y.
We Welcome School Inquiries—Special Discounts To Quantity Users

Fig. 34. 1948 EICO VTVM. The EICO model 221 was available in kit form ($33.00) or assembled ($49.95). By December the price of the kit version had dropped to $23.95 to compete with Heath's model V-1 for $24.50. (*Radio and Television News*, December 1948, p. 128)

Fig. 35. 1949 Johnson Viking transmitter. The Viking 1 had great shielding and medium power on both AM and CW. It was only crystal controlled and did not have a built-in VFO.

first kit electronic keyer on the market, shown in Fig. 36.

In 1951, Allied took the first step in a plan to compete with Heath and EICO, by introducing a kit-form VTVM of Fig. 37 for $23.95.[33] It was sold under the company's Knight brand. It would take a few more years before Allied could go head-to-head with either Heath or EICO, though even then, the company would never really be in the same league.

While it may not be familiar to very many people, Philmore has one of the longest histories in radio manufacturing. Philmore was established in 1921 and through the 1930s made a wide variety of broadcast receivers, the kind that look like furniture. It was an early maker of televisions, and from the 1940s to the early 1960s, made a large number of simple radio products in kit form. Everything from crystal sets to AC/DC table radios (some in nice Bakelite cabinets and others on bare metal chassis). In 1952 Philmore introduced a small kit-form novice transmitter, the NT-200, and in 1959 the company released a reasonably sophisticated kit-form, general-coverage receiver of Fig. 38.[34]

Late in 1952, Central Electronics introduced the Multiphase Exciter model 10A, and a single sideband adapter, the Sideband Slicer model A.[35] The company would go on to make several other transmitters in kit form, as shown in Fig. 39.

Between 1953 and 1955, the Allied Radio catalog doubled in size. This expansion was due to the vastly greater

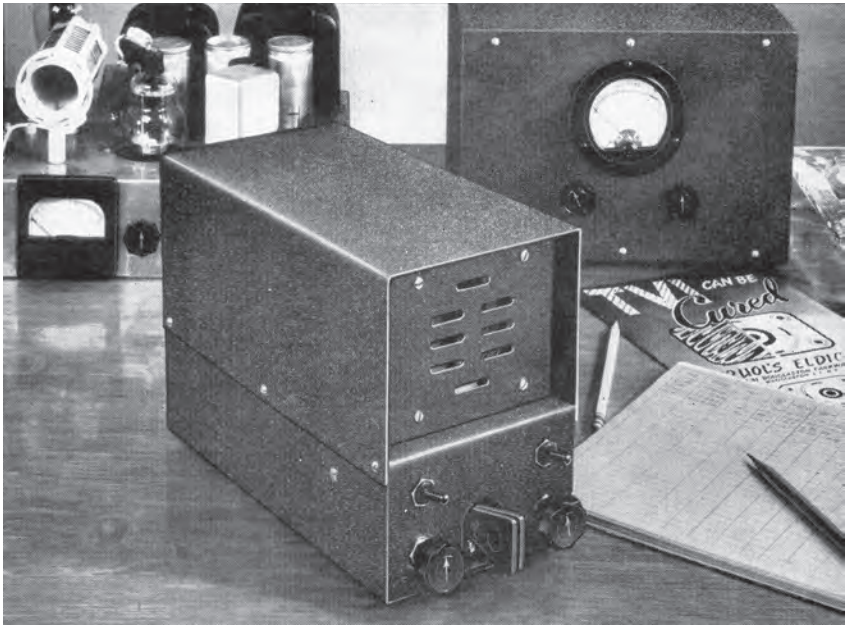


Fig. 36. 1950 Eldico electronic keyer. Eldico's EE-1 was the first kit-form electronic keyer (the company called it an electronic bug) on the market. It was based on a design by Forrest Bartlett, W6OWP, that appeared in *QST* in October 1948. (*QST*, September 1950)

- 20 megohm DC input resistance
- 6 capacity ranges
- 4 milliampere ranges
- Highest quality parts
- Clear diagrams—easy to build

VACUUM TUBE VOLTMETER KIT

ALLIED proudly presents another top-value kit—the KNIGHT Vacuum Tube Voltmeter. Designed for maximum versatility, it incorporates 2 ranges not found in any other VTVM kit: DC current in milliamps, and capacity. Perfect for measurements in high-impedance circuits, and for general all-around servicing of AM, FM and TV receivers. Invaluable in the service shop, builder's workshop, and Amateur station. Complete with handsome, all-steel case, the KNIGHT VTVM presents a professional appearance. You'll be proud to own and use this splendid test unit—and it will pay for itself many times over in time and effort saved!

Unusual Versatility. The KNIGHT VTVM reads DC and AC volts, DC milliamps, ohms, decibels, and capacity. With probes listed below, DC voltage range and AC frequency ranges can be extended for still greater versatility in servicing television receivers. Has zero-center DC scale for use in FM discriminator alignment. Checks low-voltage electrolytic condensers, as well as all other types.

Other "Plus" Features. Uses bridge-type circuit—readings are not affected by line voltage changes. Matched-pair resistors for high accuracy. Extremely high DC input resistance—for making measurements without loading circuit under test. 4½" meter—protected against burnout. Two long-life, 1½ volt clip-in batteries. Polarity-reversing switch. Zero and ohms adjust controls. One zero adjustment holds for all ranges. DC probe has 10-megohm isolating resistor. Easy to build—no previous kit-building experience required. Anyone can build the KNIGHT VTVM from the pictorial diagram alone. Pilot light for off-on indication.

30 Ranges. This versatile test unit has 30 ranges: DC volts, 0-5-10-50-100-500-1000-5000; AC volts, 0-5-10-50-100-500-1000; DC ma, 0-1-10-100-500; resistance, 0-1000-10,000-100,000 ohms and 0-1-100-1000 megs; db, —20 to +16; capacity, .00005-.005, .0005-.05, .05-5, .5-50, 5-500, 50-5000 microfarads. Input resistance on DC, 20 megohms; on AC, 10 megohms. AC range covers all audio frequencies; covers RF to 100 mc with probe listed below. Separate jack for 5000-volt range.

Handsome, All-Steel Case. Professional-looking all-steel case is finished in Hammertone gray. Maroon panel markings. Size: 6x10x5".

Supplied Complete. The KNIGHT VTVM kit is supplied with 6SN7 duo-triode tube, selenium rectifier, steel case, screened panel, punched chassis, all parts, batteries, test leads and instructions. Less wire and solder. For 110-120 volts, 60 cycle AC. Shpg. wt., 10 lbs.
83-106. With tube. NET.....23.95

83-107. High-Voltage Probe. Extends DC voltage range of above VTVM to 30,000 volts. Shpg. wt., 1½ lbs. **NET.....6.86**

83-108. High-Frequency Probe. Extends AC range of VTVM to read RF to 100 megacycles. Shpg. wt., 1½ lbs. **NET.....3.72**

Fig. 37. 1951 Knight VTVM. Following the lead of Heath and EICO, Allied announced a kit-form VTVM as its first test equipment kit. (Allied Radio Catalog, 1951)

Fig. 38. 1952 Philmore NT200 transmitter. The Philmore NT200, a simple novice transmitter in kit form, sold for $29.40, including the power supply. (*Philmore NT200 Assembly Manual*)

number of manufacturers and equipment that had come into the market over the last decade, in step with the rapid growth of the electronics industry.

Raise Your Phone Power 8 Times with
SINGLE SIDEBAND
MULTIPHASE
EXCITER
SIDEBAND SLICER
HARMONIC TVI VIRTUALLY ELIMINATED
MULTIPHASE EXCITER MODEL 10A Switchable Single Sideband with or without carrier. Double Sideband AM. Phase Mod. Break-in CW. Output approx. 10 peak watts 160 to 20 meters, reduced on 15 & 10. VOICE OPERATED BREAK-IN. With coils for one band. Wired & Tested $139.50. Kit $99.50. Coils $3.95/band.
SIDEBAND SLICER MODEL A Receiver Adapter. Selectable Single Sideband reception of SSB, AM, PM, & CW. Reduces heterodynes & interference at least 50%. Eliminates fading distortion. For receiver IF 450–500kc. Wired & Tested $69.50. Kit $47.50.
PS-1 PLUG-IN prealigned 90° phase shift network & socket $7.50.
Send for Literature
Central Electronics, Inc.
2125 W. Giddings Street
Chicago 25, Illinois

Fig. 39. 1952 Central Electronics 10A single sideband adapter. This was one of the first single sideband adapters. (*QST*, Oct. 1952)

Milestone 1953: Heath released the AT-1.

In 1953, Heath introduced their first transmitter, the AT-1, shown in Fig. 40.[36]

Fig. 40. 1953 Heath AT-1 transmitter. Heath's first transmitter, the AT-1. (Heath Catalog, 1953)

Fig. 41. 1955 Knight scope. Allied, like Heath, offered test equipment kits before expanding into amateur radio products. (Allied Radio Catalog, 1955)

In 1955 Allied expanded on the VTVM kit it had introduced in 1951. Suddenly, the company had seven instruments in its Knight line of kits. In addition to the VTVM, the company released an oscilloscope of Fig. 41, a tube tester, an RF generator, an audio generator, a signal tracer, and a VOM—all the components of a basic test bench.[37] The series was still referred to with the "Build Your Own" slogan.

Milestone 1955: Heath releases the DX-100.

In a push to become a major player, in 1956 Allied pulled out all the stops, releasing 15 new kit products (for a total of 24), and diversifying the series to include four small Hi-Fi amplifiers, two simple shortwave receivers, a simple Geiger counter (this was during the peak of Cold War-based uranium hunting), and the VFO of Fig. 42, its first amateur radio product.[38]

PACO, a division of Precision Instruments, made its entry into the kit market in 1957. The company made a dozen or so pieces of test equipment, including the scope of Fig. 43, and a smattering of Hi-Fi gear, but never ventured into amateur radio, with the exception of a tangentially related grid dip meter.[39] Though PACO would not become a major player in kits, its products were highly regarded. PACO faded way in the early 60s.

Ameco introduced the AC-1 transmitter of Fig. 44, which was a simple and very easy to build kit. It only had two tubes, plug in coils for each band, and was crystal controlled.

Fig. 42. 1956 Knight VFO. Allied's first amateur radio product, the V-44 VFO. Model numbers were not used until 1960, and some products never got one. (Allied Radio Catalog, 1956)

Fig. 43. 1957 PACO scope. PACO instruments were well designed. The assembly manuals were nearly indistinguishable from Heath's. (Radio's Master Catalog, 1957)

Fig. 44. 1957 AMECO AC-1 transmitter. This was about as simple as kit transmitters get. It has developed a devoted following. (Scott Freeberg, WA9WFA, collection)

The Big Three

In its 1957 catalog, Allied formalized its entry into the kit business by rebranding the series as "Knight-Kits" in Fig. 45. In this catalog the number of kits had grown to 34, including improved Hi-Fi amplifiers, some additional test equipment products, and its first amateur radio

you get the most for your money
in ALLIED'S own knight-kits
FINE ELECTRONIC EQUIPMENT IN EASY-TO-BUILD KIT FORM
buy Allied's own knight-kits and save—
KNIGHT-KITS are available only from Allied. They are expertly engineered, professional in appearance, easiest to build—and offer every feature essential to top performance. You get these quality kits at lowest prices because of our giant buying power. You can always be sure of the ultimate in kit value when you build outstanding KNIGHT-KIT equipment!
Test Equipment
Ham Equipment
Hi-Fi kits
Hobbyist kits
BUY WITH CONFIDENCE FROM AMERICA'S PIONEER IN ELECTRONIC KITS
Build Your Own Electronic Equipment at Big Savings
YOU GET MAXIMUM VALUE FOR YOUR KIT DOLLAR
YOU GET ADVANCED DESIGN AND TOP PERFORMANCE
YOU GET EASIEST-TO-FOLLOW INSTRUCTIONS
YOU GET EXCLUSIVE NEW ENGINEERING FEATURES
YOU GET DEPENDABLE, PREMIUM-QUALITY PARTS
knight-kits are available on our Easy Payment Plan—See Page 348

Fig. 45. 1957 Knight-Kits intro. While Allied had Knight-branded kit products in its catalog for a number of years, it never called them "Knight-Kits" before a big rebranding roll out in 1957. All of its kits were listed together in a separate glossy paper section. (Allied Radio Catalog, 1957)

kit. In 1958 there were 37 Knight-Kits in Allied's catalog, including a new "deluxe all-band amateur receiver."[40] Note that Knight-Kits were not initially given model numbers. The first Knight-Kit transmitter, without a model number, is shown in Fig. 46.

Fig. 46. 1957 Knight transmitter. Allied's first transmitter. It had no model number when released in 1957, but in 1960 was given the designation T-50. (Allied Radio Catalog, 1957)

Milestone 1958: Collins introduces the "S/Line."

Milestone 1959: First predominantly solid-state transceiver, the Hallicrafters FPM-200.

By 1958, Heath, EICO, and Allied had emerged as the three largest providers of kit products in the world, dominating the market with 90, 50 and 37 kits respectively. An EICO transmitter is shown in Fig. 47.[41] Amid this background, a number of smaller players also attempted to make their mark in kits.

There were companies with less familiar names like EMC of Fig. 48,[42] and Philmore of Fig. 49, and more familiar names like Precise (not to be confused with Precision) as in Fig. 50,[43] and

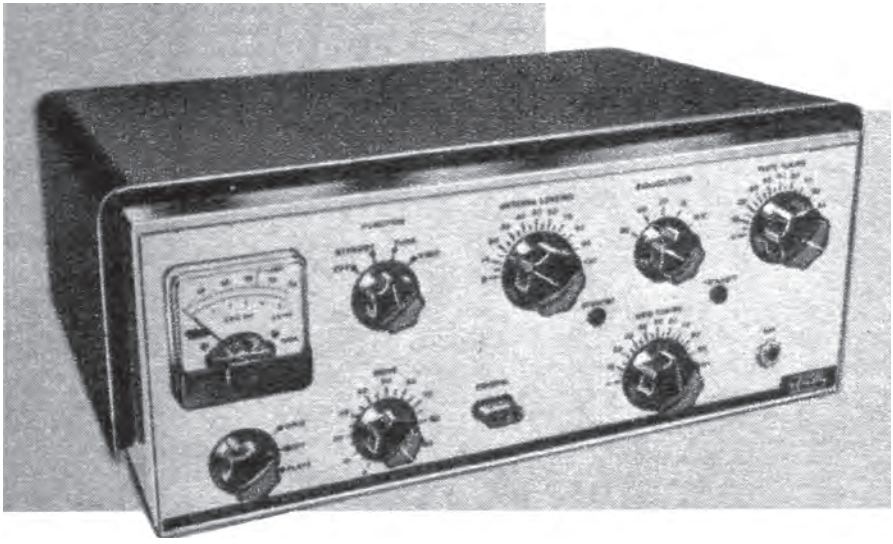


Fig. 47. 1958 EICO 720 transmitter. EICO was late to enter the amateur radio market. The 720 was the company's first product geared to hams. (EICO Catalog, 1958)

Fig. 48. 1962 EMC signal tracer. This signal tracer was one of several kits offered by EMC. (Radio's Master Catalog, 1962)

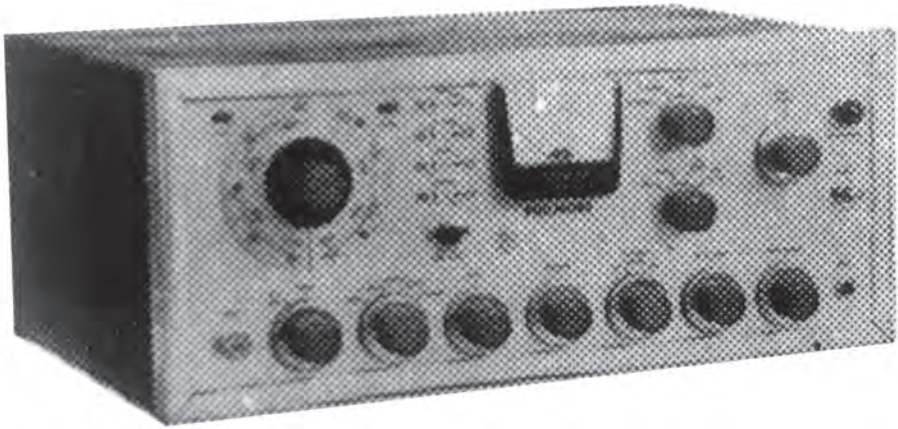


Fig. 49. 1962 Philmore Vanguard transmitter. Philmore's last hurrah, the Vanguard 6 and 2 meter transmitter. In the pages of the Radio's Master catalogs, Philmore's products, including the Vanguard, were last seen in 1962, tracking with the general decline of kit products. (Radio's Master Catalog, 1962)

Fig. 50. 1966 Precise tube tester. The Precise model 111M tube tester was one of about a dozen kits the company offered. (Radio's Master Catalog, 1966)

Fig. 51. 1966 Conar receiver and transmitter. The model 500 receiver (left) and the 25 watt model 400 transmitter are affectionately referred to as the "Conar Twins." They are rare and highly collectable. (Richard Post, KB8TAD, collection)

CONAR of Fig. 51. In 1965, National Radio Institute (NRI) introduced a small kit transmitter and receiver pair under the name Conar—a tortured portmanteau meaning "Company, National Radio."

Mercury made many products,[44] the most familiar of which were tube testers because they appeared in many drug stores and offered free tube testing. Alas, the tube testers were never offered in kit form. A kit R/C bridge is shown in Fig. 52, and an assembled drug store tube tester is shown in Fig. 53.

While most of the big test equipment makers like Hickok, Supreme, Jackson and others stayed clear of kits, RCA offered a few through the 1960s.

In 1951, when RCA Institutes established a home-study program, kit versions of some of its products were shipped to students for use as training aids.[45] A scope is shown in Fig. 54. (The scheme of using kits in electronics home-study courses was copied by DeVry Institute and Bell and Howell, both of which relied on Heathkits.) At some point, RCA began to make its kits available to anyone via mail order.

Fig. 52. 1967 Mercury 1400 R/C bridge. Mercury made a wide variety of kits through the 1960s, including this R/C bridge. (Radio's Master Catalog, 1967)

In 1960, Allied introduced the 140 pound T-400, a 400 watt transmitter[46] for AM and CW. At $395 it seemed a little expensive for a kit, especially when you read the fine print and discover that the AM modulator, single sideband adapter, low-level speech amplifier, and monitor scope are all optional. These accessories added almost $150 to the price. While it was advertised for a couple of years, it is widely believed that the T-400 of Fig. 55 was never actually sold.

Fig. 53. 1967 Mercury tube tester. Mercury is probably best known for its self-service tube testers, frequently located in drug stores. The model 204LB of the 1960s is shown here. (Radio's Master Catalog, 1967)

Fig. 54. 1962 RCA scope. The RCA WO-33A kit-form oscilloscope. RCA's kit products were originally designed and used for the company's home-study courses. Its only other kits included a VOM and two VTVMs. (*RCA Cathode-Ray Oscilloscope Manual*, WO-33A)

Fig. 55. 1960 Knight T-400 transmitter. In 1960, Allied's reach may have exceeded its grasp with the T-400 transmitter. It ran AM and CW and was offered with an optional sideband adapter (at lower left on the front panel), and an optional monitor scope. It may never have actually been sold. (Allied Radio Catalog, 1960)

Milestone 1963: Heath introduces the "SB" line.

Of the big names in amateur radio equipment outside of Heath, EICO, and Allied, only E.F. Johnson, Central Electronics, and Hallicrafters, chose to offer kit-form equipment. (Hammarlund made only kit-form AM broadcast receivers in the 1920s and 30s.)

It must be said, however, that Allied and EICO were actually not "big names" in amateur radio. Hallicrafters however was, and offered a couple of very attractive kits in the early 1960s,[47] as shown in Fig. 56.

The Decline of Kits

The decade from 1958 to about 1968 defined the golden age of kits. Kits of all description flourished, and in addition to the biggest three providers, numerous smaller companies also tried their hand at kits.

Yet the fortunes of kit makers, and those of the American electronics manufacturing industry more broadly, began to fade rapidly starting around 1970. Driven by rapid advances in discrete components and automated assembly processes, electronic products from foreign manufacturers began flooding into the United States starting in the late 1960s. These products, including radios, stereos, televisions, and consumer products of all description (including amateur radio equipment) were feature-rich, high in quality, and sold at prices far below what American manufacturers could offer.

U.S. manufacturers could not compete. Some gave up on consumer products and refocused on other markets. Others were driven out of business. Zenith is the example most often cited in these discussions, but *every* American electronics manufacturer of the 1970s was subject to the same forces that were dragging on Heath. Rapid changes in the industry, off-shore competition, automated assembly, and a changing customer base were only a few of the issues faced by all players.

If it was difficult for the major players, consider the effects on the smaller ones, which represented the vast majority of manufacturers. Many, perhaps most,

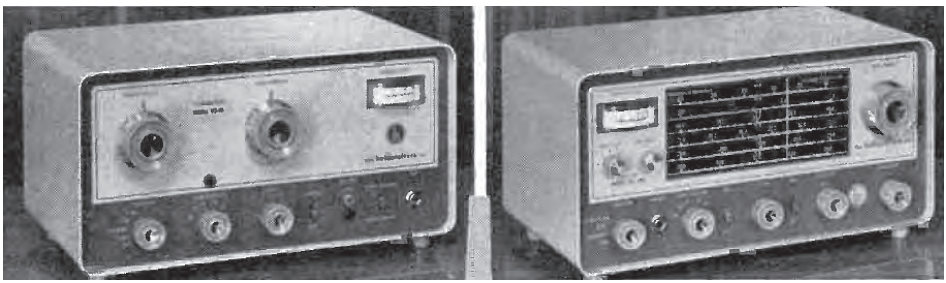


Fig. 56. 1961 Hallicrafters Hallikits. Hallicrafters offered a couple of kits in the early 1960s—the HT-40 transmitter (left) and the SX-140 receiver. The company called them "Hallikits." (Radio's Master Catalog, 1961)

of the radio and electronics companies presented here were small businesses.

These companies were not much different than any other small business, but in addition to the pressure of foreign competition, they faced a variety of other challenges. Things like starting with too much debt, insufficient capitalization, not having a sound business plan, and poor management were among the major contributors to failure. Even in the best of times, the vast majority of small business startups do not survive more than a year, and this was as true in the 40s, 50s, and 60s as it is today.

Electronics has always been a rough and tumble business, regardless of whether or not kits were involved. By the late 1960s, kit makers began to disappear, one after the other, and most of the small players were gone by the end of the decade.

In 1970, Allied was purchased by Tandy Corporation (think Radio Shack) after which Knight-Kits vanished without a trace. EICO soldiered on for a while longer, but by the mid 1970s the company had dropped virtually all of its products except test equipment. Most new products after 1978 were offered in assembled form only, and many appeared to have been made offshore and sold under EICO's brand. The company's advertising continued until 1984, though the same small ad (for the free catalog) had been used, unchanged, since at least 1980. EICO may have been on life support for a long time. It is likely that kit production had stopped by the mid 1970s, and that the company was mostly selling off whatever inventory was left.

What Made Heath Different?

There are a number of reasons why Heath did better than all the others.

First, kits were Heath's only products. While it is true that some products were also offered as fully assembled, what the company advertised and emphasized were kits. Kits are what Heath made, and Heath gave kits its undivided attention.

Second, Heath made certain that its products worked, and worked well. Heath's kits were well-engineered, useful, and durable. The parts used in Heathkits were carefully selected, of the best quality, and often were custom made. The epithet, "griefkit," had no basis in reality—it was just a cute sounding expression, like calling the Ford Explorer the Ford Exploder.

Third, Heath went to great lengths to ensure that its kits would be easy to assemble. To achieve that, Heath made the clarity and precision of its assembly manuals its top priority. The company spent as much time creating the manual as it did engineering the product in the first place. Heath's mantra was "We are never as clear as we think we are," and over the years, refined its manuals into an art form. This is neatly illustrated by comparing similar drawings shown in Fig. 57 from the assembly manuals of Heath and EICO,[48] Heath's most serious rival.

The precision of Heath's drawing is immediately evident, even to the untrained eye. While it is possible to follow either diagram, these two drawings put the time, effort, and care taken by Heath into stark relief. In addition to precision illustrations, Heath also took

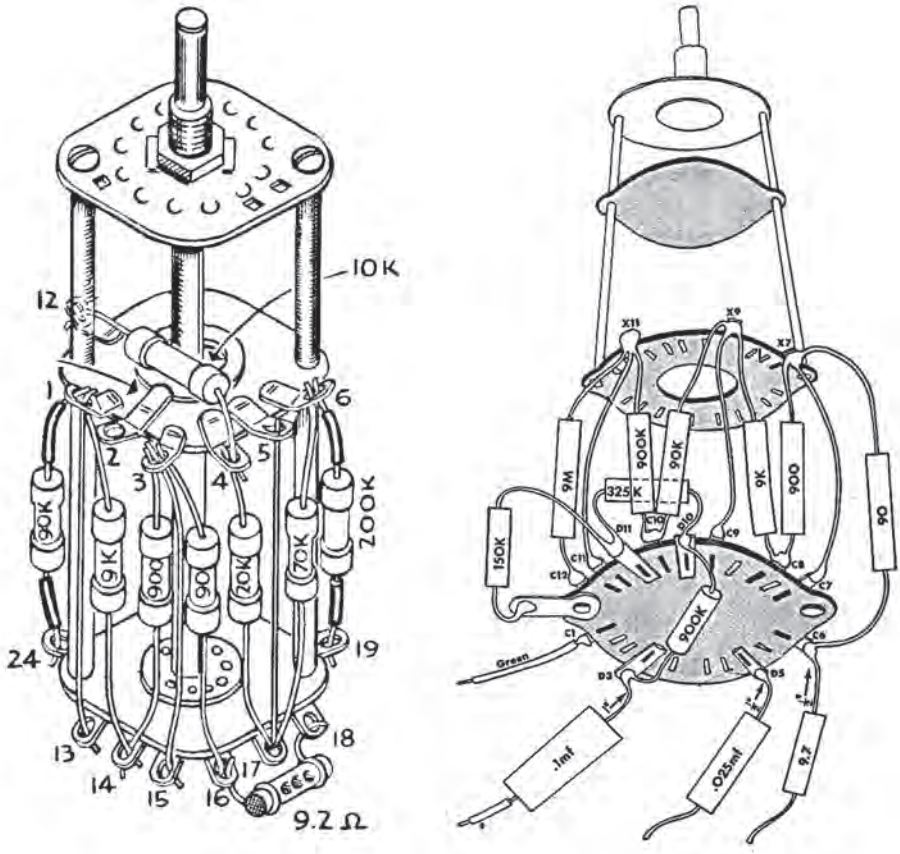


Fig. 57. VTVM range switch assembly illustrations. Heath's drawing (left) compared to EICO's, both from 1954. (*Heathkit V6* and *EICO 221 Assembly Manuals*)

the trouble to include several separate illustrations where others might use only one. And Heath very quickly began to include enlarged fold-out drawings to eliminate visual clutter and make certain that fine detail was plainly evident. Heath also invented a kind of checksum test that made errors easy to see. If, for example, the builder was told to solder wires and/or components to a terminal, the number of connections on the terminal was specified. So, for instance, if two wires were found where the check said three, it was obvious that a mistake had been made. EICO and others quickly copied this scheme.

Fourth, Heath's commitment to customer service was unsurpassed. If a part in your kit was missing or defective, you could call the company and get one mailed the same day. And it didn't matter how expensive the part was. For Heath, it was "no questions asked." If you had a problem with your kit, you could call and talk to a technician. If the technician couldn't talk you through solving

it, you could send the kit back to the factory and have it fixed. No charge. The company adopted the slogan, "We won't let you fail."

Fifth, over time, the company diversified its products far beyond test, Hi-Fi, and amateur radio equipment. There were marine kits like depth sounders and fish finders, and automotive kits that included electronic ignition systems, tune-up scopes, and a digital tachometer. The company made televisions, a trash compactor, a garage door opener, a hydraulic log splitter, and radio controlled model cars and airplanes. There were kits for photography, intercoms, smoke detectors, musical instrument amplifiers, scientific apparatus, and, of course, computers. Heath even made a motorbike, and contemplated a kit automobile. Then, of course, there was the microwave oven—the only Heathkit known to have killed someone. (It was user error.)

Sixth (and this was pivotal), in its formative years, Heath had the advantage of being owned by a man who was very rich and who cared deeply about quality and reputation. This meant that cash flow was never a problem, that corners never had to be cut, and that shortcuts didn't have to be taken. The owner could comfortably run the company out of his pocket until it became profitable enough to live on its own. He had the ability to pay for the best people, to acquire the facilities and equipment he needed, and to buy as much advertising as required to make his company well known. And he did.

All of this gave Heath the ability to think big and take chances. It set Heath apart from all others, and it catapulted the company to the forefront of the kit-making industry—a position it never relinquished.

In the end, Heath was able to hold on much longer, if for no other reason than it had the momentum of a much larger company. But the momentum finally ran out, and Heath, like all of its competitors, succumbed to the new industrial realities.

Kits Meet their Maker

Regardless of what company sold them, kits have always been sold on the same basic premise—that you could assemble a—fill in the blank—from a kit for much less money than you would spend on a fully assembled product that did the same thing.

For decades, this proposition worked well. As long as Hammarlund or Swan or Drake or whoever was doing its assembly with people wielding soldering irons, things were good for kits makers. But when Kenwood and Yaesu and Icom and a slew of others began using machines to do all the heavy lifting, the kit business model began to dissolve. Quickly.

By the early 1970s, Heath stood mostly alone.

In the 21st century, the prospects for kits as we once knew them will not change. A phenomenon like Heath or EICO or Knight will not happen again. We will not be building kit-form transceivers or oscilloscopes again anytime soon—especially with vacuum tubes, which some would argue, was the best part.

But since the earliest days of radio, kits have played an important role, and

it is crucial to understand that while the basic *nature* of kits has changed, the basic *role* of kits has not—the lower cost of kits provides access to technology for people who can otherwise not afford it. This is especially important for young people, who represent the future of science and technology. Kits still offer the best way of getting your hands on something to explore with. Exploring has always been at the root of kit building.

The kits of the future will not resemble the kits of the past. They probably won't be in big metal boxes, they probably won't have glowing vacuum tubes, and they may not require much soldering. Instead, they may be made of numerous preassembled subassemblies, and they may require a few lines of computer code (step-by-step instructions of an entirely different kind). Still, the kits of the future will be no less wondrous than the kits of the past. Building kits always has been, and always will be, about answering the question, "What would happen if…?"

If you haven't asked yourself that question recently, maybe it's time to buy yourself another kit.

Endnotes

1. EICO Catalog, 1962, p. 2.
2. *Radio News*, Nov. 1921, p. 413.
3. *Radio News*, Nov. 1922, p. 937.
4. *Radio News*, Dec. 1922, p. 1248.
5. *Radio News*, Dec. 1926, p. 725.
6. *Radio News*, Dec. 1927, p. 713; Allied Radio Catalog, 1929.
7. *QST*, Jan. 1932.
8. *Radio News*, Jan. 1933.
9. *Radio-Craft*, Jan. 1933.
10. *Radio News*, Aug. 1933.
11. Allied Radio Catalog, 1934.
12. *Radio-Craft*, Apr. 1935.
13. *Radio-Craft*, Apr. 1935.
14. Allied Radio Catalog, 1936.
15. Radio's Master Catalog, 1937.
16. Allied Radio Catalog, 1937.
17. Allied Radio Catalog, 1937.
18. Allied Radio Catalog, 1937.
19. Radio's Master Catalog, 1939.
20. Radio's Master Catalog, 1939.
21. Radio's Master Catalog, 1939.
22. Allied Radio Catalog, 1940, p. 134.
23. Allied Radio Catalog, 1943, p. 60.
24. *Radio News*, July 1946.
25. *Radio News*, May 1946.
26. *Radio News*, July 1947.
27. *Radio News*, July 1947.
28. *Radio News*, July 1946.
29. *Radio and Television News*, December 1948, p. 100.
30. *CQ*, April 1948.
31. *Radio and Television News*, December 1948, p. 128.
32. *QST*, September 1950.
33. Allied Radio Catalog, 1951.
34. *Philmore NT200 Assembly Manual.*
35. *QST*, Oct. 1952.
36. Heath Catalog*, 1953.*
37. Allied Radio Catalog, 1955.
38. Allied Radio Catalog, 1956.
39. Radio's Master Catalog, 1957.
40. Allied Radio Catalog, 1957.
41. EICO Catalog, 1958.
42. Radio's Master Catalog, 1962.
43. Radio's Master Catalog, 1966.
44. Radio's Master Catalog, 1967.
45. *RCA Cathode-Ray Oscilloscope Manual*, WO-33A.
46. Allied Radio Catalog, 1960.
47. Radio's Master Catalog, 1961.
48. *Heathkit V6* and *EICO 221 Assembly Manuals.*

About the Author

Chuck penson is an industrial archeologist and is retired from his position as historian for the Titan Missile Museum south of Tucson, Arizona. Penson has been studying the Heath Company and collecting Heathkits since about 1980. His books include *Heathkit: A Guide to the Amateur Radio Products* (a new third edition will be available in August), *Heathkit: Test Equipment Products*, *Heathkit: Hi-Fi and Stereo Products*, and *The Titan II Handbook: A Civilians Guide to the Most Powerful ICBM America Ever Built*. Penson's other interests include amateur radio (WA7ZZE), astronomy, geology (with a special interest in radioactive minerals), the intersection of science and popular culture, Cold War history, hiking, and pizza.

Chuck Penson

Navigating Two Worlds: The Amateurs and The Story of Commercial Broadcasting

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Few of the historical accounts I have read about early commercial broadcasting acknowledge the important role the amateurs played. In fact, as media historian Marvin R. Bensman has noted, "The importance of amateurs fascinated with radio has not been given the credit it deserves." He states that "amateur enthusiasts played a fundamental role in experimenting with reception and transmission;"[1] and because they knew how to build their own radio sets—an essential skill in that era before radio receivers were mass-produced and available in department stores—the amateurs were the first people to listen to the new "radiophone" stations. They were also the ones who told their family and friends about it. Thus, it would make sense for the amateurs to be included in the history of broadcasting, especially since the development of commercial radio is often told as the story of a new technology— how various inventors and engineers, working for innovative companies, designed, manufactured, and subsequently improved upon, the receivers, microphones, transmitters, and other apparatus that made broadcasting possible.[2]

The amateurs knew about this kind of experimentation from firsthand experience. The fact that many of them were aware of wireless telephony, or were even trying it out, was often mentioned in wireless communication magazines of the 1910s. Publications like *Radio Amateur News*, *The Wireless Age,* and *QST* reported on amateurs who transmitted using wireless telegraphy, but who were also experimenting with wireless telephony (Fig. 1 and Fig. 2). In mid-1919, a young amateur predicted to *The Wireless Age* that in the future, the wireless telephone would become very popular with his fellow amateurs; but for now, he said, to get good results required "the use of complicated and intricate circuits, and expensive apparatus" that most amateurs couldn't afford. However, he pointed out that amateurs were "dabblers" who enjoyed constructing their own equipment, and someone might come up with a solution that would make using the wireless telephone easier and more practical to use.[3] He was right: not only did certain "dabblers" find a way to make wireless telephony easier to use, but they went on to become the founders of some of America's pioneering commercial stations.

And yet it is rare to find much research on the amateurs who made commercial radio happen. In newspapers and magazines from 1920–1921, certain names do get mentioned, but the focus is

Fig. 1. *Radio Amateur News* cover page. (*Radio Amateur News*, October 1919)

Fig. 2. *QST*, published by the American Radio Relay League (ARRL), was a popular amateur radio magazine in the 1910s. While most of its coverage involved wireless telegraphy, it also reported on experiments with wireless telephony. (*QST*, Dec. 1919)

often on the equipment they built, rather than on them. There are also articles about the small number of commercial stations on the air at that time, and some of the people who performed on them. In many of those early radio articles, the writers state that listeners often gathered at the homes of local amateurs to enjoy the programs.[4] And sometimes, we are given a little biographical information about specific amateurs who were introducing wireless telephony to their friends and family, although the focus is usually on how the listeners reacted to what they were hearing. But an analysis of print publications (many of which are now digitized and easily available on websites like worldradiohistory.com—formerly known as americanradiohistory.com) does not provide much insight into who these amateurs were, or more importantly, why some of them decided to remain solely in the amateur radio world, while others decided to enter commercial radio (and a few decided to do both).

Omitting the Amateurs

In the 1910s, most of the publications that wrote about radio were mainly directed at an audience of amateurs, and often focused on wireless technology. But gradually, in the period from 1920 to 1922, as commercial radio emerged, a number of new magazines came along, aimed at a more mass appeal audience: magazines like *Radio Digest* and *Radio in the Home* covered the business of radio, or wrote about the performers and the announcers, or informed the listeners about what was on the local stations. And many more newspapers began to pay attention to the local broadcasting stations too, as radio was gradually transitioning from being a fad to a national obsession, with millions of listeners from coast to coast. This was good news for newspapers and magazines, which now received lots of advertising dollars from the manufacturers of radio receivers. And it was equally good news for the manufacturers, who had more new customers than ever before. But once again, whether told as a story of the growth of a successful new business, or the story of how the audience was expanding, the amateurs who put some of those new

stations on the air were usually missing from the narrative. And I also found that years later, when history of broadcasting textbooks were written, they too often glossed over or downplayed the contributions of the amateurs.[5] And more surprising, in some cases, the names of key amateurs were excluded from the origin stories of some of the commercial stations they helped to create.

To cite one example of this, the first written history of pioneering Detroit radio station WWJ, was published by the *Detroit News* in 1922, only two years after the station, then known as 8MK, made its debut. Yet the book says nothing about Clyde E. Darr (8CB, later 8ZZ), the influential amateur radio operator who was president of the Detroit Radio Association.[6] It was Darr who conducted some of the experimental broadcasts that helped get the station on the air. This omission is puzzling, given that publications from that time stated Darr was the first amateur in the Detroit area to broadcast voice and music.[7] There is even a historical photograph showing one of the *Detroit News*' executives observing Darr (Fig. 3) as he broadcast from his home.[8] Years later, in 1989, Elton Plant, one of the original broadcasters at the station, self-published a memoir. It offered some interesting recollections of 8MK's early days; but once again, the importance of Darr's experiments was overlooked. And that is my point: a modern reader seeking

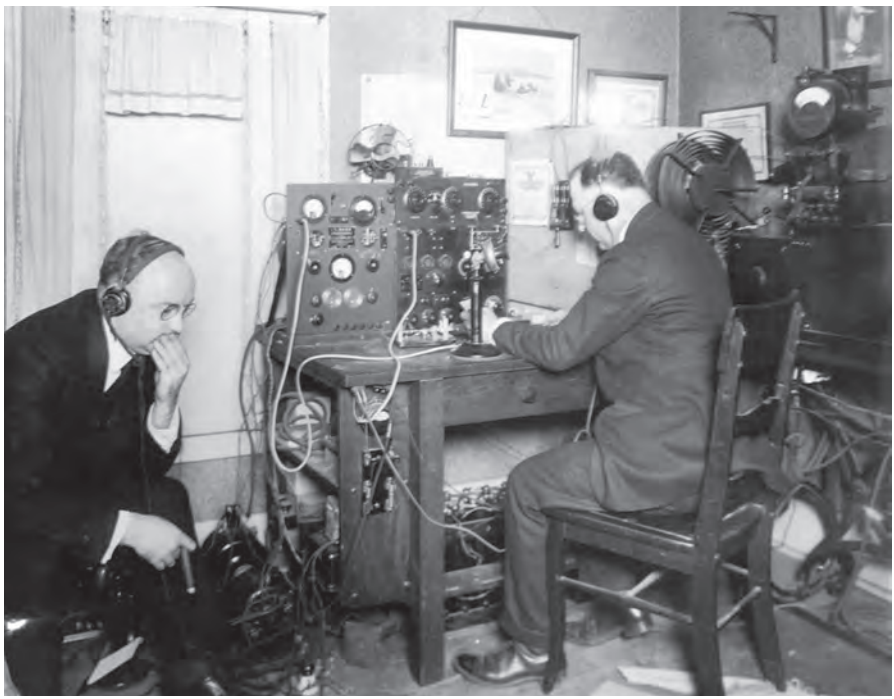

Fig. 3. Clyde Eldon Darr, right, handles the controls of his home amateur radio rig, while *Detroit News* building superintendent W. E. McGuire, left, listens. (*Detroit News*, 1920)

information about how commercial radio came to be might come away with the impression that the amateurs weren't involved at all.

The Importance of the Wireless

To better understand the development of commercial radio, and the role the amateurs played, we need to go back to the 1910s. Of course, in that era, there was no "commercial radio" as we understand that term today. Instead, there were numerous businesses that relied on wireless telegraphy to send and receive orders for merchandise, or to communicate with customers in distant regions of the country. Some executives even used the telegraph to arrange important meetings, such as when major league baseball executives sent telegrams to the league president to let him know they wanted to have a conference.[9] Long distance telephony existed, but it was expensive (in January 1915, for example, when long distance service between New York and San Francisco began, a three minute call cost $20.70);[10] and even with advances in availability, telephone service was still not widely available in some regions. Thus, experienced telegraphers were still very much in demand, as were messengers, who could get a telegram from the local telegraph office to its intended recipient as quickly as possible.[11] In addition to various businesses, journalists relied on the wireless too; it was an essential tool for news and sports reporters: when they were covering a story far from their office, they could send it by telegraph, and it would arrive in time for the next edition. Many newsrooms had telephones by then, but it was often easier and cheaper to send the story via the wireless, and many reporters even traveled with their own telegraphers.

It wasn't just business executives and reporters who made use of the wireless. By the 1910s, there were a growing number of individual stations, operated by amateur hobbyists, most of whom communicated by Morse code to fellow hobbyists all over the country. Some of the most eager proponents of amateur radio were also involved with the newly formed ARRL, and in addition to chatting with other amateurs, they also spent time relaying messages, whether from ships at sea or amateurs in distant parts of the country. Amateur radio was such a popular pastime that by 1916, the radio inspector for New England, Henry C. Gawler, estimated that there were about 600 amateurs in his district alone; many of them were "high school lads and younger."[12] And while the majority of the amateurs were male, the call books of that time showed the names of a few women. One was Miss Cecil Powell, the private secretary to ARRL founder Hiram P. Maxim (Fig. 4). A newspaper in her home state of Connecticut said she was the first woman amateur in that state and praised her for building her own wireless set;[13] in 1916, she had the call letters 1WX. By 1917, she was teaching wireless classes to women who wanted to be ready to help the war effort; if the United States entered World War I, trained women wireless operators would take the place of the men who had been sent overseas to fight.[14]

Fig. 4. Cecil Powell, 1915. (*Wireless Age*, May 1915, p. 586)

Early Radio Experiments

But while most amateurs were content to send, receive, and relay messages, there were several wireless operators who saw other possibilities. One of the earliest was a West Coast inventor and engineer named Charles "Doc" Herrold, the founder of the Herrold College of Wireless and Engineering in San José, California (Fig. 5). Herrold's station was perhaps the earliest to offer regular programs of voice and music: local newspapers reports in July 1912 stated that he had begun broadcasting experimental concerts—with the music provided by phonograph records—to an audience of

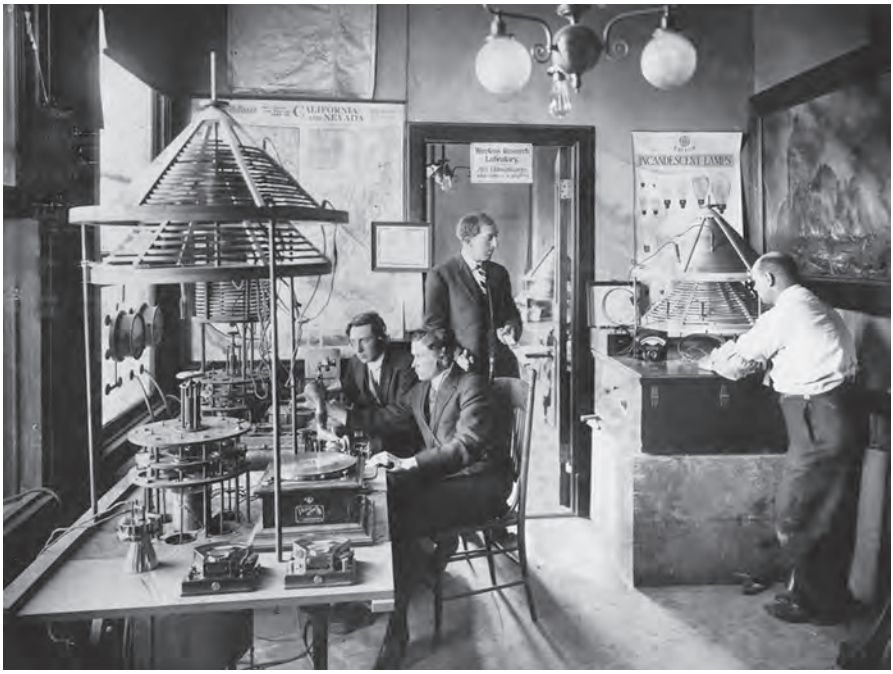

Fig. 5. Photograph of Charles (Doc) Herrold's San Jose California radio laboratory, circa 1912. Herrold is standing in the doorway. (*Radio Amateur News*, July 1919, p. 11)

amateurs "within a radius of 100 miles." His listeners seemed pleased with the broadcasts—they even sent him requests by telegraph.[15] The broadcasts continued off and on during the next several years. In late 1916, Herrold told a reporter he believed "about 300 owners of wireless apparatus" were listening to his music concerts. And listeners praised how clear the broadcasts sounded.[16]

Meanwhile, in Medford Hillside, Massachusetts, about six miles from Boston, two recent Tufts College graduates, Joseph A. Prentiss and Harold J. "Jimmy" Power, started an experimental wireless telephone station and opened a studio in late 1915. The two had been active in the Tufts Wireless Society (where Power had been its president), and now they had a station of their own, as well as a new business, the American Radio and Research Company (AMRAD), which manufactured equipment for amateur radio operators. As newspaper articles attested, Power used the wireless to perform experimental broadcasts, as early as March 1916. He sent out music concerts, much to the amazement of people who heard the sounds of phonograph records, rather than the sounds of Morse code. Most likely, he was using the Tufts Wireless Society call sign 1JJ, as the AMRAD wireless station was first licensed as 1XE in December 1916 or January 1917, according to the Radio Service Bulletin of February 1921.[18]

If you were reading about Herrold, Power, Prentiss, and others in the publications of 1915–1916, you would have noticed that certain terminology was very different from what we use today. While these men were involved with what we would call "ham radio," you would not have seen that phrase very much, nor were they described as "ham radio operators"—they were generally called "amateur wireless operators." The term "ham" could occasionally be found in the amateur radio publication *QST* by 1917;[19] but it had not yet transitioned to its current positive meaning. In the 1910s, publications like *QST* tended to use it scornfully, referring to inexperienced operators, folks who "hammered" away at their key, folks who were "hamming it up" until all hours, or speaking about operators with inferior or improperly used equipment, who were referred to—with quotes around them—as "hams" or even "so-called HAMS."[20] The word as we use it today would not be seen in newspapers and magazines until the early-to-mid-1920s.[21] In fact, the word "radio" wasn't commonly used in the 1910s either, at least not the way we use it in modern times. You could see the word applied to organizations like the Institute of Radio Engineers, which was founded in 1912, or to the growing number of amateur wireless clubs. But when it came to discussing experimental broadcasting to a mass audience, you were more likely to see terms like "radiophone" and "radiotelephone," or even "wireless telephone," as in an October 1919 newspaper article about another pioneering amateur, Westinghouse engineer Frank Conrad. He operated amateur station 8XK from his garage in Wilkinsburg, Pennsylvania (near Pittsburgh) at that time, and sent out experimental broadcasts via the "wireless telephone."[22] And by the early 1920s, people who listened to these broadcasts were referred to as BCLs (Broadcast Listeners),[23] while loyal fans were referred to as "radio bugs."[24]

Looking at what other amateurs were doing at the dawn of commercial broadcasting, some had begun using their stations as a source of entertainment in cities that did not yet have a commercial broadcasting service. One good example of this was Dr. William D. Reynolds, a dentist based in Colorado Springs, Colorado. In September 1919, he had already become the superintendent for all the amateurs in the state. But he also announced that he planned to do experiments in wireless telephony and install a radiophone station.[25] By 1920, using the call letters 9JE, he began sending out music concerts, in addition to overseeing amateur radio clubs and activities in Colorado. However, Reynolds became so interested in wireless telephony that he gave up his dental practice to devote himself to it,[26] as well as inventing new equipment that would improve the sound of his broadcasts. His high-powered station became well known in Colorado and the western United States, and throughout 1920–1921, he continued sending out regular programs.[27] At one point, he even used his station to talk about the future of wireless telephony with local businessmen attending a Chamber of Commerce meeting.[28] In mid-1921, he relocated to Denver, where, as 9ZAF,

Fig. 6. Doc Reynolds, 1923. (https://commons.wikimedia.org/wiki/File:William_D._Reynolds_at_radio_station_KLZ_in_Denver_(1923).jpg)

he continued to demonstrate innovative ways to use the wireless, providing the city with music concerts, weather reports, and information about local events. And in March 1922, Doc Reynolds (Fig. 6) became the owner and operator of KLZ, Denver's first commercial station; his wife Naomi was one of the first female broadcasters at the station.[29]

Adapting to Commercial Radio

For some amateurs, the choice seemed to be binary: either they remained in commercial radio or they returned to amateur radio. But a few amateurs decided to do both. One good example of this was Irving Vermilya, a Cape Cod, Massachusetts, amateur (1HAA, then 1ZE, and later W1ZE), shown in Fig. 7. He was very active in the ARRL, where he became the division manager for New England in the early 1920s. He spoke at many amateur radio conferences, and mentored numerous amateurs (including one young woman, Eunice Randall). Vermilya had been interested in amateur radio since he was a boy—he even met Guglielmo Marconi.[30] And five decades later, he was still every bit as devoted to amateur radio as he had been during his youth. Although I have done extensive research on his life, I have yet to find out what made him decide to become a commercial broadcaster. I know that in 1922, Vermilya was asked to build a commercial station (WDAU) that would operate at the Slocum & Kilburn store in New Bedford, and he then stayed on to manage it. And when the owners had financial problems, he relocated the station (now known as WBBG) to his home, so that it would continue to operate.[31] Sometime in 1925, he moved the station to the New Bedford Hotel (many early

Fig. 7. A rare photo of Irving Vermilya, W1ZE, at his home in 1955. (Author)

stations had studios in hotels), under the call letters WNBH, and he served as its general manager.[32] He was still managing the station in the early 1940s, and later became its transmitter engineer.[33] But I still don't know why he decided to remain in commercial radio for more than four decades. Given his passionate dedication to promoting amateur radio all over the United States, it would be interesting to know how he was able to switch back and forth between both of those worlds for so many years.

It is also worth mentioning that even Hiram P. Maxim understood the potential impact of commercial radio, and it did not seem to worry him. In prepared remarks at the ARRL's first annual convention in September 1921, he predicted that the "radiophone" would soon become such a pervasive and popular means of communication that people all over the country would be able to hear sessions of congress, or concerts, or church services.[34] And Maxim would be heard on commercial stations on several other occasions, promoting amateur radio in general, and the ARRL in particular.[35]

As Maxim predicted, commercial broadcasting continued to grow in popularity in the early 1920s. Interest in amateur radio did too; a look at amateur radio publications like *Radio Amateur News* (renamed *Radio News* in mid-1920) shows a growing number of amateur radio clubs, especially at YMCAs, high schools, and colleges.[36] But gradually,

some unexpected problems arose. As so many new commercial stations proliferated across the country, the broadcast listeners and the amateurs—who had generally gotten along well up to this point—suddenly developed a contentious relationship. This was especially true in 1922–1923, when commercial radio stations were still being asked by the Department of Commerce to share a limited number of frequencies.[37] During this time, the broadcast listeners were accusing the amateurs of causing unnecessary interference while they were trying to enjoy their favorite programs, and some commercial radio fans even called the radio inspector to complain.[38] Meanwhile, the amateurs were pushing back against what they saw as attempts to blame them for atmospheric conditions that weren't their fault.[39] But interference was a very real problem, and it was often unintentional (but annoying). Historian Marvin R. Bensman attributes it to the lack of precision in some early radio equipment: in that time before crystal control of radio frequencies had been perfected, sometimes, "stations could not always adhere to a wavelength with any degree of accuracy, and receivers also experienced drift."[40] And the radio inspectors in various regions did have to intervene and try to find compromises, until such time as improvements in equipment, along with opening up more frequencies on the AM band, helped to alleviate some of the problems. There were cases where the radio inspector was also a ham; here is Charles Kolster (1RI) giving the code exam to prospective hams in this hobby (Fig. 8).

But while some publications made it seem like the amateurs and the broadcast listeners were bitter enemies, that was an exaggeration. More often than not, they found ways to peacefully coexist.

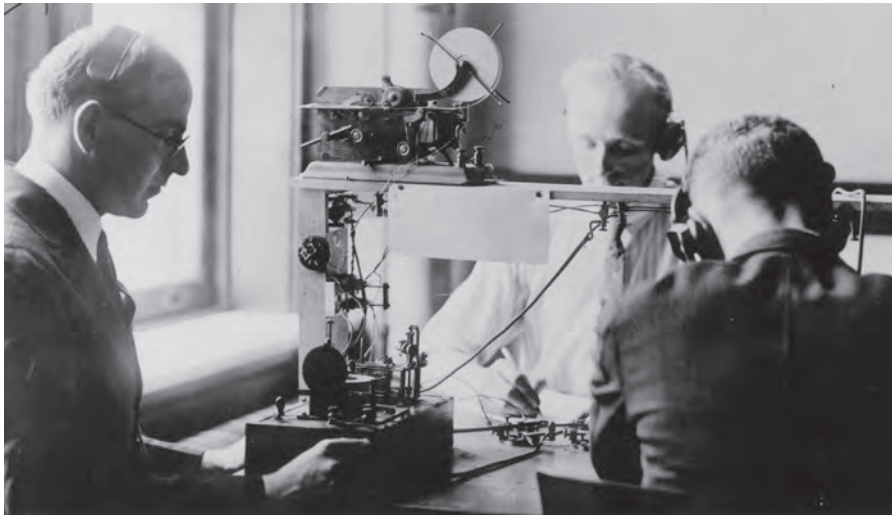

Fig. 8. Division 1 radio inspector Charles Kolster (1RI) giving the code exam to two prospective amateurs circa 1922. (Author)

In many cases, they were friends, or even colleagues. Irving Vermilya was not the only ham radio operator who maintained amateur calls and belonged to a local ham radio club, but who also had a regular job at a commercial station. Another example is someone I mentioned in my 2018 *Antique Wireless Association Review* article about 1XE/WGI: Eunice Randall, one of early commercial radio's first female broadcasters. Eunice, shown in Fig. 9, was a loyal amateur—1CDP, and later W1MPP. Having been mentored by Vermilya, she was well-versed in everything from sending Morse code to building and repairing equipment. She worked at AMRAD, which manufactured radio receivers, and she was a well-respected "draftslady," known for her precise technical drawings. On AMRAD's pioneering commercial station 1XE/WGI, she was one of the most popular announcers, doing everything from reading news, to announcing the songs, to sending out the nightly bedtime story for the kids. And while she left commercial radio after AMRAD began having serious financial problems circa 1924, she remained actively involved with amateur radio for the rest of her life.

To cite another example, Clarence V. Purssell was involved with amateur

Fig. 9. This 1921 photo shows Eunice Randall, 1CDP, on the air in the 1XE studio in Medford Hillside, MA. (https://www.bostonradio.org/essays/wgi)

radio as far back as 1915, when he was using call letters 1MP from his home in Dorchester, Massachusetts. He went to work as an engineer for the Edison Electric Illuminating Company, which was eager to put a commercial radio station on the air in 1923. The company first operated WTAT, a "portable," which was transported in a truck (Fig. 10) and set up at various events (radio conferences, county fairs, etc.); and in 1924, WEEI went on the air. Purssell, who rose to the position of head of Edison's radio operations division before leaving to start his own business, was one of the engineers who set up the portable and operated it, working with station announcers to make sure the event went smoothly.[41] He also worked with other Edison engineers to maintain and improve the equipment used by WEEI.

This was a common occurrence: radio station owners often relied on the amateurs to help with setting up or repairing equipment. And given how the earliest stations often had their studios at the plant where the receivers were manufactured, anyone who came to perform on the air often was doing so in an environment where they were surrounded by wires and tubes. Having an engineer on scene during the broadcast was necessary

Fig. 10. This 1924 photo shows portable station WTAT, owned by the Boston Edison Company. Clarence Purssell and three colleagues are standing by the REO Speedwagon that contains the equipment, ready to go out and set up a remote broadcast. (Author)

Fig. 11. Piano music live on WBZ, from the original studio on Page Blvd, Springfield. In 1921, WBZ's first studios were at the Westinghouse plant where the radios were manufactured. (https://www.thebdr.net/wbz-one-of-the-first-is-90/)

in case something went wrong. One early photograph from WBZ Radio, then located in Springfield, Massachusetts, at the Westinghouse plant, shows a female vocalist, a pianist, and engineer Horace R. Dyson (1AUV) looking on—with a somewhat worried expression (Fig. 11). Stations in those early days also utilized amateurs to provide Morse code practice for anyone who needed it. (Code practice was even a feature of early commercial radio: some stations offered it at least once a week, along with news from the various local ham radio clubs.[42] Since many of the listeners were also amateur operators, it was seen as a goodwill gesture.)

A Pioneering Commercial Station

After the United States entered World War I, radio experiments with voice and music were halted; the government finally allowed these broadcasts to resume around April 1919,[43] when the amateurs were also allowed to get back to operating their stations. Interest in amateur radio was even stronger than before the war: by 1920, there were about 6,000 stations in operation.[44] And of course, 1920 was the year that "commercial broadcasting" was born. While it is not within the scope of this paper to engage in the annual debate over which station became the first commercial station to broadcast, suffice it to say that by the middle of 1920, there

were numerous amateurs who were not only communicating with each other, but also sending out music concerts to a mass audience. These concerts were so popular in certain cities that "dancing by radio" was becoming a fad: listeners would dance to the songs they heard coming out of their receiving set.[45] And among the many amateurs sending out occasional concerts and sports and talks, there were at least four wireless operators in 1920–1921 whose stations most closely resembled what commercial radio would become known for: they broadcast music on a regular schedule (including occasional live performances), they sometimes broadcast sports scores or news headlines or weather reports, and they asked listeners to let them know if the broadcasts were being heard.[46] These stations were the previously-mentioned 1XE (Harold J. Power), 8XK (Frank Conrad), 9ZAF (William D. Reynolds), along with the "Detroit News Radiophone," 8MK.

The *Detroit News* radiophone station was unique, in that it was the first commercial broadcasting enterprise owned by a newspaper. This pioneering station went on the air in mid-August 1920 as 8MK (and by 1922, it was known as WWJ). When 8MK made its debut, the listening audience was mainly comprised of amateur hobbyists; it was not known whether anyone except the amateurs (and their families) would care about a radiophone station. It turned out the listeners cared a lot: within days, reception reports were coming in from all over Michigan and even into Ontario, Canada, and the reaction was very enthusiastic—although some listeners were skeptical. They couldn't believe the music was coming from a radio set, and they thought perhaps someone had hidden a phonograph somewhere.[47] Demand for more programs increased, as radio fans gathered at the homes of local amateurs to enjoy the *Detroit News* broadcasts. By 1922, when the so-called "radio craze" took hold and radio became a national obsession, newspapers began to see radio as competition. Some tried to avoid mentioning what the local stations were doing, and others listed the evening's programs but nothing else. But the owners and editors of the *Detroit News* never saw radio as a threat. Rather, William E. Scripps, whose family owned the newspaper, saw broadcasting as another way to inform (and also entertain) the public, and a complement to the newspaper. 8MK even broadcast nightly news bulletins, read by Al Weeks, the newspaper's drama critic, when he was not announcing the evening news reports.[48] Listeners who wanted more information were encouraged to purchase the next edition of the *News*.

On August 31, 1920, when the *Detroit News* published its page 1 announcement of the beginning of a commercial broadcasting station, the newspaper acknowledged that this service was "for the benefit of the wireless devotees of Detroit." And the *News* requested of the amateur operators who received the broadcast that they promptly notify the *Detroit News* Radiophone Department.[49] The newspaper enclosed a form that the operators could fill out and mail in, letting the radio department know the names and locations of those who had

listened—this would help in determining how far the broadcast had traveled and which parts of Michigan were able to receive it (and it would also give the *News* a mailing list to use in the future).

After several nights of experimental music concerts, the "Detroit News Radiophone" made its official debut, broadcasting Michigan election returns on August 31, 1920. The page 1 announcement, inviting amateurs to listen and tell their friends, used the call letters "8MK." But to this day, there are questions about which amateur was the actual owner of the station's 8MK call letters. Some accounts say they belonged to Michael D. Lyons; he edited a local amateur radio publication, the *Detroit Radio News*, assisted by his brother Frank, who was also an amateur.[50] In the 1919 Department of Commerce call book, Michael was listed as 8AN. There is evidence that Michael was involved with the installation of the new station's equipment: Elton Plant, who worked there in 1920, recalled that it was Michael who "[installed] the De Forest OT-10 transmitter in the radiophone room on the second floor of the *Detroit News* building."[51] But in the June 1920 Department of Commerce amateur radio call book, there was no mention of an 8MK; in fact, the call letters do not seem to have been assigned till later that year: in the August 17, 1920 issue of Lyons' own Detroit-based publication, the 8MK call first appeared, and it was credited to H. (Howard) Bowman, a newspaper reporter for the *News* and later the *Detroit Free Press* (Fig. 12 and Fig. 13). The following year, Bowman was using 8HH, according to the June 1921 Department of Commerce amateur radio call book, which said the 8MK call letters now belonged to the *Detroit News* itself. But whoever was the owner of the 8MK call, the experiment with radiophone broadcasting was a big success. Numerous reception reports came in, and each successive night, more people reached out to say they liked what they were hearing. Among the first listeners to

Eighth District.

8AI J. G. Johnson, 2240 Lawrence, Toledo, Ohio.
8AM F. E. Lyons, 463 Green Ave., Detroit, Mich.
8AN G. Kleinert, 2055 West Grand Blvd., Detroit, Mich.
8AO E. Clark, 81 Spokane, Detroit, Mich.
8AQ E. G. Boyes, 170 West Willis, Detroit, Mich.
8AR H. Tank, 356 Ferndale, Detroit, Mich.
8AU F. Murphy, 150 Hogarth, Detroit, Mich.
8BA E. H. Koehn, 989 Meldrum, Detroit, Mich.
8BF G. Wedemeyer, 511 Kingsley, Ann Arbor, Mich.
8BJ R. F. Hershelman, 325 Cleveland, Detroit, Mich.
8BO Earl Ensign, Toledo, Ohio.
8BZ G. Flower, 65 Hooker, Detroit, Mich.
8CB C. E. Darr, 137 Hill Ave., Highland Park, Mich.
8DG F. D. Johnson, 1335 Hill St., Ann Arbor, Mich.
8EJ P. G. Schlotterbeck, back of 1917 Washtenau, Ann Arbor, Mich.
8FA A. M. Stellwagen, 312 East Jefferson, Ann Arbor, Mich.
8FX Cass Technical High School, Detroit, Mich.
8GR George Norris, 1784 Brush, Detroit, Mich.
8KB Keith McGary, Avery St., Detroit, Mich.
8KH B. Fitzgerald, Kirby and Brooklyn, Detroit, Mich.
8LK J. E. Williams, 723 Oakland Ave., Ann Arbor, Mich.
8LL E. Ryan, 2105 Senator, Detroit, Mich.
8LV Dutch Eslinger, 523 Miller Ave., Ann Arbor, Mich.
8MC M. C. Bartlett & Hammond, 180 Parker, Detroit, Mich.
8MG W. Updike, Detroit, Mich.
8MK H. Bowman, 171 Kenilworth, Detroit, Mich.

Fig. 12. *Detroit Radio News* Calls Heard, August 1920, showing calls heard on the air in the eighth call district, which included 8MK, assigned to H. Bowman in Detroit, Michigan. (*Detroit Radio News*, Vol. 1, No. 7, Aug. 17, 1920)

DETROIT
RADIO NEWS
A PERIODICAL FOR DETROIT, TOLEDO AND NEARBY CITIES
VOL. 1. NO. 7 Tuesday, August 17th, 1920. PRICE 10 cents

Fig. 13. *Detroit Radio News* header. (*Detroit Radio News*, Vol. 1, No. 7, Aug. 17, 1920)

weigh in was Clyde Darr, whose experiments in broadcasting voice and music were so important to 8MK's development. Darr was excited to let everyone at the *News* know he heard the broadcast and found the signal "splendid." He said the technical quality was "far above expectations."[52]

But, as I mentioned earlier, amateurs approached commercial radio differently. Unlike Denver's William D. Reynolds, who ultimately left amateur radio to pursue ownership of a commercial radio station, Darr is an example of a well-respected amateur who decided not to seek a career as a commercial broadcaster, nor work for a commercial station. A talented artist and illustrator (his work sometimes could be seen on the cover of *QST*,[53] as well as in several local newspapers), he already had a job he enjoyed. And so, after his 1920 experiments with voice and music, he returned to amateur radio. By 1922, he had become the manager of the central division of the ARRL, and spent his free time giving informational talks to amateur radio clubs, and teaching interested young people about the hobby. Darr was beloved in amateur radio circles, and when he died in 1929, the large number of hams he had mentored were deeply saddened by the news. But while he seemed happy to leave further advancements in commercial radio to others, it certainly seems that commercial radio in Detroit owes him a large debt of gratitude.

Frank Conrad Becomes Famous

When 8MK was making its August 1920 debut, Frank Conrad was still using his Pittsburgh amateur station, 8XK, to entertain the public, while he maintained an active role in the ARRL. *QST* paid tribute to Conrad's station in September of that year, praising him for how the set that he built sent out such a strong and clear CW signal;[54] many local amateurs tried to emulate what he had designed. When he was not developing new equipment or relaying messages via Morse code, he spent his time working as an engineer for the Westinghouse Electric and Manufacturing Company. Several nights a week, Conrad sent out a music concert from his garage studio, much to the delight of his many listeners, who were happy he was still entertaining them. By May, his Saturday evening broadcasts were being

heard by thousands of people, within a 600 mile radius. His concerts featured a wide variety of musical genres: opera, folk music, popular songs, even some blues; and on one occasion, there was even some live music played by his colleague William Thomas, on a "wireless piano."[55]

But Conrad would soon become known for his role in the founding of pioneering commercial station KDKA in Pittsburgh, and his name quickly became national news, as did the accomplishments of KDKA—thanks in large part to the publicity department of his employer. As a manufacturer of many popular household appliances, Westinghouse was a dominant force at that time, and consumers frequently saw ads for Westinghouse toasters, irons, stoves, and coffee percolators in numerous magazines and newspapers.[56] Given the company's well-known name, when Westinghouse embraced the new mass medium of radio, many publications treated it like news. And when the announcement was made that the Westinghouse "wireless telephone" station would broadcast election returns, the story was reported in Pittsburgh,[57] and newspapers in other cities also picked it up.[58] (And amateurs in numerous states were also promising that they would be listening for the results, which they would then relay to anyone interested. In Charlotte, North Carolina, some amateurs planned to have gatherings, where friends and family could be present as the returns were received.)[59]

Westinghouse made effective use of its publicity department throughout 1921 and 1922: the (false) claim that KDKA was "the first radiophone station in the world" began to appear in newspapers all over the country, along with praise for Conrad's role as the visionary who made it possible.[60] Conrad's other role—as a widely-admired amateur—was seldom mentioned, although his skill as a design engineer often was. Unfortunately, other inventors and innovators, including Harold J. Power, William D. Reynolds, and Charles "Doc" Herrold, found that their achievements were overshadowed (or completely ignored) by the mainstream press, even though they had been doing experimental broadcasts for as long as Conrad. The problem was that Power, Herrold, Reynolds, and others were either individual entrepreneurs or employed by smaller companies; this meant they did not have the budget or the publicity staff to get their story out the way Westinghouse did. As a result, Frank Conrad became a household name; Power, Reynolds, and Herrold did not.

Interestingly, while the *Detroit News* did place several promotional advertisements about their station in magazines, the ads ran mainly in publications read by members of the newspaper industry, such as a 1922 ad in *Editor and Publisher*.[61] In fact, during 8MK's first months on the air, publicity about the station could mainly be found only in the pages of the *Detroit News*.

Although some pioneering amateurs didn't get the attention that they deserved from the national press, others became local heroes, beloved and appreciated in their community. In New Mexico, for example, Ralph W. Goddard was the

Dean of Engineering at what was then called the New Mexico College of Agriculture and Mechanical Arts (today New Mexico State University) in Las Cruces (see Fig. 14). He was the faculty advisor to the school's amateur radio club, which he had helped to organize in 1921, and he taught classes in both wireless telegraphy and wireless telephony. Circa 1920, Goddard began operating experimental station 5XD, and he traveled throughout the region, giving talks, and demonstrating current trends in broadcasting. Widely admired in both New Mexico and neighboring Texas, Goddard was frequently quoted by newspapers in both states, and his experiments with 5XD were frequently reported. Then, in April 1922, he put station KOB on the air. While it operated at the college, it offered the kinds of programming one might expect of a commercial station: a studio orchestra, talks by local newsmakers, up-to-date weather and crop reports, and various live entertainers. Goddard continued to use his engineering skills to improve KOB's sound, such that by the late 1920s, the station was using a 10,000 watt transmitter.[62] He operated the station until his untimely death on New Year's Eve 1929–30: he was accidentally electrocuted in the transmitter room, while doing maintenance of some kind (since he was alone when it happened, nobody knew for certain how the accident occurred).[63] Today, few people outside of New Mexico know his name, but when he died, Ralph W. Goddard was mourned by thousands of his engineering colleagues, as well as students, amateur radio operators, and listeners to KOB.

Fig. 14. Ralph W. Goddard, 5XD, New Mexico's first broadcaster. (Courtesy Archives, New Mexico State University)

Throughout 1920–1922, amateur broadcasters in many cities were finding that the arrival of commercial radio gave them a chance to reach a wider audience. Of course, not every amateur who had been sending out voice and music wanted to join a commercial station. As mentioned earlier, Detroit's Clyde E. Darr was a good example of someone who was happy remaining an amateur radio operator only; and he was not alone. Louis Falconi was another influential amateur who seemed uninterested in becoming a commercial broadcaster. Falconi, an electrician and later a radio salesman, was a New Mexico colleague of Ralph Goddard. Falconi lived in Roswell, where he operated station 5ZA; both he and Goddard were active members of the ARRL. Falconi's amateur radio work

was frequently mentioned (and praised) in magazines like *QST*; when he won the 1921 Hoover Cup, an award given to the country's outstanding amateur station, it was not only reported in the amateur radio world, but in local newspapers too.[64] But unlike Goddard, there is little evidence that Falconi ventured into commercial radio; he seemed content to operate 5ZA (later W5ZA) along with his wife Eunice, who was also a fan of amateur radio.

Some other amateurs decided they would not become announcers or station managers in commercial radio, but they would work at a commercial station as an engineer, like Clarence V. Purssell did. Another devoted amateur who made that decision was William B. Gould 3rd, 1NP (later 2NP after he relocated to New Jersey). Gould, one of the earliest African-American amateurs in Massachusetts, became the chief engineer of WTAG in Worcester, Massachusetts, when it debuted in 1925, and he remained there till 1929. Some other amateurs devoted their time to designing new and better radio equipment, which could be used by either amateurs or commercial broadcasters. Charles "Doc" Herrold continued his wireless experimentation, and in December 1921, he put commercial station KQW on the air in San José, where he still ran his school, now known as the Herrold College of Engineering and Radio.[65] As for Frank Conrad, although he had made a name for himself in Pittsburgh with his popular musical concerts on 8XK, once Westinghouse put KDKA on the air, he stopped his concerts and continued his job as the company's assistant chief engineer. Subsequently he began experimenting (Fig. 15) with the shortwave band.[66] He remained a popular guest speaker at amateur radio clubs and engineering conferences, renowned as a prolific inventor and the holder of about 120 patents.[67]

Other Options for the Amateurs

In 1920–1921, that transitional period before commercial radio became America's dominant mass medium, amateurs had an easier time moving back and forth between the world of commercial broadcasting and the world of ham radio. In fact, it seemed that nearly every city had at least one amateur like Frank Conrad, or Dr. Reynolds, someone with a high-powered amateur station, who enjoyed using it to provide free entertainment and information to the local community. That is why many amateurs were upset with the Department of Commerce in January 1922, when it issued a ruling that forbade amateur stations from sending out music and news,[68] thus creating a strict separation between what the amateurs and the commercial broadcasters were allowed to do. And while some of the amateurs were happy to return to the world of sending and receiving messages, other amateurs wanted to keep a foot in both worlds, and they were upset that they no longer had that option.

But while they could no longer play music or report about sports, the amateurs found that the growing popularity of commercial radio provided a new option: for those who didn't want to join a commercial station but who still wanted to participate in the development

Fig. 15. Frank Conrad after KDKA, in the mid to late 1930s. During this time, he worked for Westinghouse, focusing on shortwave projects and other experiments. (Author)

of radio broadcasting, there were new opportunities in journalism. With more stations on the air, newspapers were eager for radio editors who knew something about the technology and also knew the people running the local broadcasting stations. To give a couple of examples, in Boston in 1921–1922, the *Boston Traveler*'s radio editor was Guy Entwistle (1AL). He had studied at Tufts College, where he was friends with Harold Power and Joe Prentiss; while there, he used the Tufts Wireless Society's call letters, 1JJ. As a radio editor, he reported on all the Boston stations, although much of his focus was on what the amateurs were doing. It is thanks to his reporting that I first learned about Eunice Randall's broadcasting career, and first saw Irving Vermilya's name. At the *Boston Globe*, there was another amateur, Lloyd Greene (1HA), who was also a designer of amateur radio receivers. At the *Boston Herald*, the radio editor, Joe Toye, was not an amateur—but he was a very knowledgeable reporter who knew everyone in the local radio scene and paid close attention to what the local stations were doing. And sometimes, the *Herald* made use of an amateur to do a profile of a local broadcaster with ham radio ties: for example, Sumner B. Young (1AE) wrote a profile of Irving Vermilya in 1923.[69] And this was not just a Boston phenomenon: in those formative years, newspapers from the

Brooklyn Daily Eagle to the *Los Angeles Times* had radio editors who covered the amateurs as much as they covered the commercial broadcasters. Perhaps the best-known radio editor of that time was Jack Binns: back in 1909, he became a hero, as a young wireless operator on a ship (Fig. 16). His quick thinking saved lives: when his ship, the *Republic*, was struck by a cargo ship, the *Florida*, and began to sink, he sent out a wireless call for help (CQD—today SOS). He then used his telegraphy skills to coordinate the rescue effort as other ships came to assist.[71] Later, he embarked upon a career in journalism, and was the radio editor for the *New York Tribune* in the early 1920s; his columns were often republished in other newspapers.

Fig. 16. Jack Binns. (Jackbinns.org)

As commercial radio continued to advance, the amateurs had their own publications that followed their careers and reported on their clubs. But as time passed, what the amateurs had done to help make commercial radio possible was forgotten, replaced by a focus on the radio networks, with their hit programs, famous entertainers, and popular announcers. Now and then, a fan magazine would mention that a certain movie star or a popular musician was also involved in ham radio,[70] but with every year, the mentions happened less frequently, despite the fact over the years, ham radio continued to attract new fans—and a number of well-known people in the media participate in it—big names like news anchor Walter Cronkite (KB2GSD), an ARRL member, and radio and TV star Arthur Godfrey (K4LIB).

This article has named only a few of the many amateurs who either built or founded (or both) the most successful commercial stations, but at least it makes a start. Some may see this as an arcane or unimportant piece of radio trivia. However as a media historian, I like to see the entire story told, and when it comes to the story of the amateurs in commercial radio, there is so much more that is worth telling. The amateurs played an important part in the development of commercial radio: in the 1910s, they were the experimenters, and then many went on to be the engineers, announcers, station managers, and even station owners. We owe these men and women a debt of gratitude, and I would like to see them receive the credit they deserve.

Endnotes

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Industrial Designers: Making Radios Sexy

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Industrial design—the design of things manufactured on an assembly line—did not exist until the late 1920s. The pre-machine-age era (i.e. prior to the assembly line) was characterized by handcrafted items, such as furniture, which were designed and created by individual artisans. Consequently, the task of making a product was ad hoc. "Industrial design" as a profession would take some time before it emerged. Early mass-produced goods—such as refrigerators, irons, toasters, and of course, radios—tended to be crude and visually gaudy, but most consumers didn't mind. In fact, they were delighted. The fact that they were available at reasonable prices and offered benefits that never existed before was most important. Function, not appearance, was the primary concern among consumers.[1]

Early Years of Applied Art

Simple design strategies, otherwise known as applied art, were commonly used to enclose and adorn products. Extraneous cosmetic surface decorations, such as flowers or pin striping, were sometimes applied to the radio's cabinet. Another strategy used exotic grille cloth patterns (like the flower pattern in RCA's 103 speaker or the forest scene in Philco's model 87 console). Another tactic used elaborate brass escutcheon plates on the control panel to dress up the area around the main tuning knob. Finally, and most commonly, armoires and desk sets were repurposed to hide or disguise a radio's components (i.e. radio, amplifier, speaker, batteries). These techniques were generally used to add a modicum of "charm" to a technical product that had little appeal for women.

Kolster Radio, under the leadership of Frederick Kolster, used the services of a famous New York interior designer by the name of Elsie de Wolfe to make a connection with women. Fig. 1 shows a 1925 Kolster ad, which says: "Kolster Radio owes its exterior charm to Miss Elsie de Wolfe, the world's foremost authority on furniture and related decorations."[2]

While Elsie may have been a good interior designer, she seems to have been out of her element in the field of radio design. Her designs were not much different than those from other manufacturers' and not long afterward Kolster went into receivership.[3]

Splitdorf and Philco chose to use the flashy artwork approach[4] as shown in Fig. 2. Splitdorf's 1925 radio ads for their Japanese-inspired sets (the Mikado and Geisha) said: "Every creation is individually decorated by hand by Nippon artists." Similarly, Philco, who in 1928 had just entered the radio manufacturing business, used colorful pictures of flowers to decorate their metal coffin-style table sets. Philco's ad read: "Enhanced

with color effects by Mlle. Messaros, one of the foremost colorists in the decorative arts. The colors are applied by hand under her personal direction."[5]

Philco incorporated a bit of resume inflation in their ad, perhaps as a way to compete with Kolster's use of Elsie de Wolfe. It turns out that Mademoiselle Messaros was actually Hungarian, not French; and she was only a minor artist in the Philadelphia area, but no matter.

Contests

Mrs. Hugo Gernsback, the wife of *Radio News* magazine's editor, had a unique idea: sponsor a contest to solicit design ideas from the magazine's readers. She believed women were becoming more involved in choosing a radio receiving set and should have a say in how they look:

> "The reason is that the lady of the house must be pleased first. She demands a certain piece of furniture that will harmonize with other furniture in the room. Hence radio sets are assuming more and more the look of a beautiful piece of furniture."[6]

The cover of the March 1926 issue boldly invited readers to "Draw Your Ideal Radio Set" offering $1,000 in prizes. Prizes were awarded separately in both men's and women's categories.[7]

How did that turn out? Well, by the looks of it, they were ho-hum. Much like Elsie de Wolfe's efforts, the winning designs were mere echoes of furniture styles already on the market. (Fig. 3 and Fig. 4)

But, four years later, the folks at Westinghouse decided to give the idea of a radio design contest a try themselves. They felt that a contest might yield some interesting radio designs if it was presented to a very wide and more diverse audience. So, starting in September 1930, they flooded the nation with advertisements promoting their "Radio Idea Contest" in major magazines such as the *Saturday Evening Post* (Fig. 5) and *Colliers,* as well as a host of newspapers. A total of $10,000 would be awarded in prizes. First prize was $5,000 (equivalent to over $77,000 in today's dollars) to be awarded in cash or as an all expense trip to Europe. As the Great Depression was starting to set in, this was a very significant amount of cash at a time when nearly 25 percent of the country was unemployed.[8]

Raymond Loewy was chosen by Westinghouse to be one of their six judges soon after they hired him to design their radio cabinets.[9] By all accounts the contest was a smashing success with 150,000 entries received from all over the world. The names of the winners were announced on many radio stations and in most major newspapers in January 1931.

Peter Copeland, a 27 year old unemployed architect from Newark, NJ, won first prize, and Lucy K. Wilkes, a housewife from New York, came in second. Understandably, all of the winners took the cash prize rather than the alternative all expense paid trips.[10]

When Westinghouse introduced the Columnaire skyscraper-style grandfather clock radio, which Raymond Loewy

designed, they proudly claimed that the radio's small footprint was due to many contestants' wanting a radio that took up minimal floor space.[11]

As technology advanced and as products matured, "style" slowly became a more important factor in the purchasing decision. *Radio Retailing*, in its 1929 survey of "What does the Public Want?"[12] rated appearance #3 in importance on the list (behind AC operation and tone), whereas in 1927 appearance was only rated #6 (after simplicity, tone, AC operation, distance reception, and price).

The Great Depression caused all sales to drop dramatically, encouraging all manufacturers to pay even more attention to the appearance their products.

Even as the depression wore on, technological developments were still occurring in most every facet of life: automobiles, airplanes, skyscrapers, plastics, as well as the explosive growth of radio broadcasting. All of these things had an influence on product design.

The quest for sleeker aerodynamic shapes to achieve greater speeds spilled over into the designs of ordinary household products to the point where streamlining became a design fad. Aerodynamic motifs were being applied to almost every product, whether it was relevant or not.

Skyscrapers, too, affected furniture design as exemplified by the stair-step bookcases created by Paul Frankl. European design movements such as minimalism, which grew out of the Bauhaus School of Germany, made domestic designers rethink their own design philosophy.

"Form follows function" became the new design mantra; extraneous design elements that did not add to a product's function were minimized or eliminated.

The fast pace of progress made clear to most manufacturers that a new kind of design specialist was now required, namely, an industrial designer: someone who could coordinate a product engineer's capabilities with the manufacturer's need to minimize costs and the customer's desire for an appealing design. They were also able to visualize how new materials, such as Bakelite plastic, could be used to produce more decorative cabinets.

A few supremely talented people emerged to take on these new challenges from which Walter Dorwin Teague, Harold Van Doren, Henry Dreyfuss, Norman Bel Geddes, and Raymond Loewy were just a few who would go on to nearly become household names. They all came from a wide assortment of backgrounds such as commercial art, theater stage-set design, advertising, as well as engineering, and they all had a natural gift for creating exciting product designs.

In 1938 the American Designers Institute (ADI) was formed wherein John Vassos became their first president. Later a similar but competing group, the Society of Industrial Design (SID) was formed in 1944, choosing Walter D. Teague to be their president. Eventually, they agreed to merge in 1965 and form the Industrial Society of America (IDSA), whose membership is open to anyone.

Fortune magazine, in their 1934 article titled "Both Fish and Fowl," discussed the new profession of industrial

design and highlighted the comparative practices of the most prominent designers. The abbreviated table in Fig. 6, taken from that article, gives a candid look at how lucrative this profession was, at a time when nearly 25 percent of all Americans were unemployed.[13]

"When Will Radios Be Styled for Sales Appeal?" asked Walter Dorwin Teague in his 1933 article in *Electronics* magazine. He was convinced that "present sets [are] still in the Model T stage."

Alongside Teague's article, the National Alliance of Art & Industry posted an announcement for a clinic titled "How to Style Radios for Increased Sales" to be held at the Hotel White on Lexington Ave. in New York City. They wanted to encourage an exchange of ideas about how to make radios more stylish and appealing to consumers. Speakers at the clinic included Norman Bel Geddes, Donald Deskey, Henry Dreyfus, Raymond Loewy, Gilbert Rohde, Harold Van Doren, Russel Wright, and, of course, Walter Dorwin Teague, among others.[14]

Bakelite and radio, discovered almost simultaneously, were made for each other. Not only was Bakelite used to make the front panels of the early home made radios, but also used for the front panels of the first production radios as well. In addition, Bakelite's insulating properties made it perfect for components such as tube bases, insulators, and capacitors.

Bakelite was developed by Leo Baekeland in 1907 and patented in 1909. In 1922 the Bakelite Corporation was formed, and under its new director of advertising and public relations, Allan Brown, it was aggressively marketed as "the material of a thousand uses."[15] In 1924 Leo became famous enough to make the cover of *Time* magazine.

By 1927 the last of the Bakelite patents ran out and competitors started springing up everywhere. The field became crowded with new products such as Durez, Beetle, Plaskon, Insurok, and Tenite. Undaunted, Bakelite kept flooding trade publications, such as *Radio Engineering*, *Communications,* and *Electronics,* with ads strongly emphasizing the concepts of "design" and "styling" as shown in Fig. 7.[16] In 1935 they even ran a series of seven ads titled "Bakelite Presents Radio Cabinet Design." Each ad featured a contemporary design sketch, which could be used to make a smart looking molded radio cabinet by anyone.

Designer Profiles and Some of Their Radio Designs

To get an appreciation of how industrial design influenced radio's rapid acceptance into the home, we need look no further than to the designers themselves, so, the rest of this paper will showcase some of America's most significant designers. They are grouped into five categories consisting of short biographical sketches accompanied by a sampling of their radio designs as follows:

1) USPS stamp honorees (8)
2) Other major designers (9)
3) Lesser-known designers (10)
4) Company employee (in-house) designers (3)
5) International design (1)

USPS Stamp Honorees

The U.S. Post Office recognized the importance of industrial design in the development of our technological history by issuing two sets of 12 stamps honoring some of the most prominent men and women who made contributions in this field. One set of 12, issued in June 2011, honors 12 industrial designers, six of whom played a part in creating interesting radio cabinet designs. Another set of 12 stamps, issued in 2008, exclusively honored Charles and Ray Eames, and they also had an impact on radio design. These stamps are shown in Fig. 8.

Raymond Loewy (1893–1986) is probably the best-known industrial designer. He was born in Paris, studied engineering, served in the French Army in World War I, and arrived in the United States in 1919. He worked as a fashion illustrator and costume designer before opening his office in New York in 1929. He was one of the founders of the Society of Industrial Designers (SID) in 1944. He was on the cover of *Time* magazine in 1949, wrote *Never Leave Well Enough Alone* in 1951, and established a Paris office in 1952. By 1960 his office, Raymond Loewy Associates, had a staff of 180. Loewy's major designs included the 1932 and 1934 Hupmobiles, the 1934 GG-1 locomotive for Pennsylvania Railroad, the 1947 and 1953 Studebakers, the 1962 Avanti, the 1966 Exxon logo, and many others too numerous to mention.[17]

Raymond Loewy's earliest assignments were for the Colonial Radio Company and Westinghouse, for which he designed the Colonial Globe and Columnaire radios, respectively. Later his firm designed products for Hallicrafters and the Emerson Radio & Phonograph Company. The Hallicrafters SX-42 shortwave receiver was actually designed by Richard Latham (1920–1991) who was the Director of Design at his Chicago office. Fig. 9 shows a few of Raymond Loewy's designs.

Norman Bel Geddes (1893–1958) was born in Adrian, Michigan, and he studied briefly at Cleveland Institute of Art and the Art Institute of Chicago. Norman began work as an advertising draftsman in Chicago and Detroit and established a highly successful career in theatrical set design in New York beginning in the 1920s. In 1927 he began work as an industrial designer at the suggestion of Ray Graham of Graham-Paige Motors Company, where he developed automobile prototypes. His futuristic and visionary transportation designs earned him the nickname of "the P. T. Barnum of industrial design." In 1932, he published his book, *Horizons*, and, in 1939, designed General Motors' Futurama at the New York World's Fair. Based on his studies of transportation, he published *Magic Motorways* in 1940, an inspiration for the interstate system of highways.[18]

Radio collectors may remember him best for his Emerson Patriot, which was used as the icon for his stamp. In the 1930s, while working for Philco, he designed two console radios plus a chairside along with a clock that could be used as a decorative accompaniment with a radio. He designed other radios for Federal and Majestic, but apparently, they were never produced. Fig. 10

shows a collection of his radios, some of which, unfortunately, were never manufactured.

Donald Deskey (1894–1989) studied architecture at the University of California, Berkeley, California, and painting at the California School of Design, the School of the Art Institute of Chicago, the Art Students League of New York, and then in Paris (1920–1922). He operated a New York office with Phillip Vollmer from 1927 to 1931, specializing in furniture and lighting. He won the competition for the design of Radio City Music Hall and his work there (1931–1934) popularized Art Deco. He was one of the founders of the Society of Industrial Designers (SID) in 1944. His firm developed notable packaging designs for consumer products such as Joy, Cheer, and Gleem toothpaste.[19]

Deskey designed the "New World" and "Futura" moderne console radios for Stromberg Carlson in 1945. The New World was still being sold in 1955—quite a feat for a product meant to be marketed for only one season. He also filed a design patent for a moderne chairside radio, but it is not clear if that was ever produced. However, his design style was picked up by others, as can be seen from the John Paul Jones whiskey advertisement (Fig. 11).

Henry Dreyfuss (1904–1972) was born in Brooklyn, New York, to a family in the theatrical materials supply business. He completed studies as an apprentice to Norman Bel Geddes in 1924, and produced 250 theater stage sets for a number of theaters between 1924 and 1928. He opened his own office in 1929. His major clients included Bell Telephone Labs, AT&T, John Deere, and Polaroid. His autobiography, *Designing for People*, was published in 1955, and *The Measure of Man* came out in 1960. He was the first president of the Industrial Design Society of America (IDSA) upon its formation in 1965.[20]

Dreyfuss' design firm did work for RCA for a short time in the 1950s, and some of the radios his firm created are shown in Fig. 12.

Charles Eames (1907–1978) worked with an architectural firm in St. Louis (1925–1927), and then as a partner of Gray and Eames (1930–1937). In 1937 he became head of the department of experimental design at Cranbrook Academy of Art and worked with Eero Saarinen investigating plastics. They won a MoMA furniture design competition in 1941. He married Ray Kaiser in 1941 and they moved to Los Angeles to design film sets for MGM, but continued experimenting with plywood. Their workshop became part of the Evans Products Company in 1943, laminating glider parts. At war's end, the company turned to production of Eames' chairs. He sold rights for his chairs to the Herman Miller Furniture Company in 1946. Eames produced some of the most creative design work of the century in furniture, film, and exhibits.[21]

Charles Eames' chance meeting with Alexander Girard, another industrial designer who worked at Detrola Radio and was also experimenting with bent plywood, led him to create a few

bent plywood designs for a number of companies including: Bendix, Emerson, Farnsworth, Hamilton Radio, Federal Telephone & Radio, Majestic, Magnavox, Stromberg Carlson, and Zenith. A few of his designs can be seen in Fig. 13 and Fig. 14.

Ray Kaiser Eames (1916–1988). After World War II, she became her husband's professional creative partner in a range of design projects, and in 1981, was awarded honorary membership in the Industrial Designers Society of America.[22]

Walter Dorwin Teague (1883–1960). This U.S. industrial designer who was born in Decatur, Indiana, is considered by many to be the dean of industrial design. He studied at the Art Students League in New York from 1903 to 1907. He worked as an illustrator, establishing his own commercial art studio in 1911. By the mid-1920s, he was well known for his elegant advertising drawings. He left advertising to open one of the first industrial design firms in 1927, receiving his first contract with Eastman Kodak in 1928. He was on the Board of Design for the 1939 World's Fair, where he also designed the Ford and U.S. Steel pavilions. Teague's best-known book, *Design This Day-The Technique of Order in the Machine Age*, was first published in 1940, as the first book on the whole subject of industrial design, tracing the development of modern design and outlining necessary techniques to the solution of design problems. He also wrote *Land of Plenty: A Summary of Possibilities* in 1947. In 1944, he was one of the founders of the Society of Industrial Designers, becoming its first president. After World War II he became a major consultant for Boeing, designing many of their interiors.[23]

Fig. 15 shows a collection of some of Teague's early radio designs. Most people know him for his famous mirrored radios, but notice that the patent for the circular radio design (D92,578) is in the name of John D. Brophy. He was Teague's administrative assistant. In the 1920s Teague did some radio design work for the National Carbon Company, the makers of Eveready batteries, and after the war he did some design work for Scott Radio Laboratories.

Russel Wright (1904–1976) attended the Art Students League in New York and the Columbia University of Architecture. He began his career in the theater as an apprentice with Norman Bel Geddes, then as a stage designer. He began a business with his wife Mary in 1930, designing and producing spun-aluminum accessories for the home. He designed American Modern furniture for Macy's in 1935, and, in 1939, American Modern ceramic dinnerware. His 1953 melamine plastic Residential table service was one of the earliest designs in plastic. He closed his office in 1958.[24]

Wright designed a few radios for the Wurlitzer Company, the same outfit that developed the most colorful and exotic iconic jukeboxes of all time. The very moderne Lyric and the M-4-2 are two stylish radios he designed and are shown in Fig. 16. These radios appear to be very rare because the only pictures available anywhere are the same photocopies that appear in Wright's biographies.

Other Major Designers

John Richard "Jack" Morgan (1903–1986) was born in Guatemala City, Guatemala. He joined Harley Earl's Art & Color group at General Motors in 1929. In 1934 he became chief product designer at Sears; Roebucks' department, and began a private practice starting in 1944. His *Waterwitch* outboard motor for Sears was in the 1934 *Machine Art* Show. With Sears until 1943, he designed a number of products including a washing machine, upright vacuum cleaner, and kitchen cabinet ensemble. From 1947 to 1952 he was a partner with Mel Boldt in Chicago, and from 1948, he was a design consultant for the Dormeyer Corporation.[25] Fig. 17 shows some of his radio designs for Sears.

Ben Nash (1882–1951) was one of the pioneering industrial designers that helped mold the profession and establish standards for it. In addition to actual product design, he had an excellent reputation as a packaging expert. He believed that it was important to sell products in an attractive consumer friendly container to increase sales. His book *Developing Marketable Products and Their Packaging* (1945) is a textbook on that subject. Ben also had a weekly radio show titled "Art and Industry," which aired on a Newark, NJ station. He started out as an artist for the American Lithographic Company and then became staff artist for *New York World* magazine. While art director for J. Gude Company, outdoor advertisers, he created the first electric sign ever installed on Broadway. Afterwards, he set up his own design consultancy in New York City with an office in Rockefeller Center (i.e. 30 Rock). He also taught marketing at New York University.[26] Fig. 18 shows some of Nash's designs for Philco.

Jean Reinecke (1909–1987) attended Kansas State Teachers College, and studied art at Washington University in St. Louis, Missouri. He started as a display artist at General Display Studios in St. Louis, soon becoming a partner. In 1930 he opened a Chicago office to work on displays for the Chicago Century of Progress Exposition (1933–1934). In 1934 he joined with James Barnes to form Barnes & Reinecke. In 1938, he designed the Toastmaster model 1B9 for McGraw Electric Company (later McGraw-Edison), the first to exploit the curvature of chrome shells. He designed Scotch tape dispensers for 3M starting in 1938, including its ubiquitous 1940 plastic disposable dispenser. In 1948, he sold his interest in the partnership and established J. O. Reinecke & Associates, with offices in Chicago, and later, Pasadena, California, where he designed until 1986. He was president of SID in 1952.[27]

Arguably, the most creative radio designs emerged during Reinecke's association with the firm of Barnes & Reinecke from 1934–1948. Some of those radios, such as the Sengbush desk set and Charlie McCarthy set, are pictured in Fig. 19.

Sundberg & Ferar was formed in 1934 by Carl W. Sundberg and Montgomery Ferar, who met each other while working at General Motors. The firm has designed for Sears & Roebuck, and the Whirlpool Corporation, and in the 1970s, they designed mass transit systems for many U.S. cities. Although both men

retired in 1975, the firm remains active to this day.

Sundberg & Ferar designed some beautiful plastic sets for Kadette in the 1930s. Later, they designed radios for Sylvania and jukeboxes for Seeburg. Some of their work can be seen in Fig. 20.

Carl W. Sundberg (1910–1982) attended Wicker Art School in Detroit and in 1927 began his career designing custom car bodies at Dietrich Body Company. He then worked in plastics design at Kurz-Kasch, Inc. and then later at General Motors (GM).[28]

Montgomery Ferar (1910–1982) received a bachelor's and master's degrees in architecture at MIT in 1932, and studied in Europe in 1933. He worked for several architectural firms in Boston before moving to Detroit to join General Motors Art and Color Section where he met Carl Sundberg.[29]

Van Doren & Rideout was formed in Toledo, Ohio, by Harold Van Doren and John Gordon Rideout. The association lasted from 1931 until 1935. During this time, they created some of the most beautiful and iconic skyscraper radios ever designed for Air King. They also designed the Scottie radios for Remler. Fig. 21 shows a few of their designs.

Harold Van Doren (1895–1957) was born in Chicago, Illinois, and graduated from Williams College in 1917. He studied at the Art Students League in New York (1920–21), and in Paris (1922–24). In 1927, he became assistant director of the Minneapolis Institute of Arts. After Rideout left, the firm became Harold Van Doren & Associates, and in 1940 he relocated to Philadelphia. That same year he wrote his book, *Industrial Design: A Practical Guide*. In 1944 he expanded his firm to include a New York office, known as Van Doren, Nowland & Schladermundt.[30]

In the 1950s, Van Doren did design work for the Philco Appliance Division. There he created the infamous "V-handled" refrigerator that could open either left-to-right or right-to-left depending which part of the V handle was pulled. It could be used in any kitchen without having to specify which side of the door should have the hinges.

John Gordon Rideout (1898–1951) studied architecture at the University of Washington, but left school to serve in the navy in World War I. He worked in the 1920s as a graphic designer in Chicago. In 1935 he left Van Doren and started his own firm in Cleveland, Ohio. In 1944 he joined with architect Ernest Payer to combine industrial design and architecture.[31]

John Vassos (1898–1985). John was a U.S. industrial designer who was born in Constantinople (now Istanbul, Turkey), the son of a Greek publisher. While serving on a suicide minesweeper in World War I, he was torpedoed, rescued, and landed in Boston in 1919. He studied art and illustration with John Singer Sargent at the Fenway Art School. He came to New York in 1924 where he studied at the Art Students League and opened an industrial design studio. He published and illustrated a number of books from 1929 to 1931. In 1933 he established the first internal design department at RCA, remaining its consultant until 1964. He was the first president of the American

Design Institute (ADI) in 1938. During World War II, with a predecessor of the CIA, he helped organize the Greek underground and developed camouflage techniques. He was elected the first chairman of the board of IDSA when it was formed in 1965.[32] A number of his designs are shown in Fig. 22.

George W. Walker (1908–1993) was an automotive designer who trained at Otis Institute, Los Angeles, in 1916, continued at Cleveland School of Art, and headed his own industrial design office in Detroit by the 1930s. His firm worked for Nash (1937–1945) and in product design as well. His role at Ford began in 1945 as an independent consultant working on the 1949 Ford, Ford's first true post-war model. He became Ford's first vice president of styling in 1955, where he remained until his retirement in 1962.[33]

Fig. 23 shows Walker's design patent for the Detrola Pee-Wee radio, which he did during his pre-automotive career as well as two radio escutcheons he designed for Grigsby-Grunow. Also shown are some of his futuristic automobile sketches.

Lesser-Known Designers

Melvin H. Boldt (1917–1981) was a U.S. industrial designer who was in partnership with John Morgan from 1947 until 1952, when he left to form Mel Boldt Associates in Chicago, Illinois. He started consulting with Zenith in 1955 upon the death of Robert Budlong. Mel Boldt Associates remained in business until 1990, designing countless consumer products for Zenith, Presto, Brunswick, and Moen, among many others.[34] For Zenith, the firm designed radios, remote controls, clocks and video recorders. For Amana/Raytheon, he designed microwaves and refrigerators. For National Presto Industries, he designed countless blenders, toasters, irons and specialty products such as egg cookers, butter melters, and a cordless rechargeable toothbrush. His staff generally included about 15 designers.[35] Fig. 24 and Fig. 25 show some of Mel Boldt's many designs for Zenith.

Robert Davol Budlong (1902–1955) was a U.S. industrial designer born in Denver, Colorado, who studied art at Cummings School of Art, Des Moines, Iowa, graduated from Grinnell College, Iowa in 1921, studied art at the Chicago Academy of Fine Art, and opened an advertising office in Chicago. He began his career in industrial design in 1933 with the Hammond Clock Company and consulted with Zenith from 1934 until his death.[36] Fig. 26 shows some of Budlong's designs for Zenith.

Jon William Hauser (1916–1999) was a U.S. industrial designer who was born in Sault St. Marie, Michigan, and began his career with General Motors in 1936. He worked for Chrysler, Sears & Roebuck as director of design (1943–1945), Dave Chapman (1945–1946), Barnes & Reinecke (1946–1949), Reinecke Associates (1949–1952), and as executive vice president of Raymond Loewy's Chicago office (1960–1961). He established his Chicago office, which then became Hauser Design Inc. in 1970. After retirement, he served as visiting professor of design at the University of Illinois in

Champaign-Urbana.[37] Fig. 27 shows some of Hauser's designs for Philco and Motorola.

Clarence Karstadt (1902–1968) worked for John Morgan at Sears & Roebuck in the 1930s, where he designed his classic Silvertone "Rocket" radio. While at Sears he designed many other consumer products such as irons and vacuum cleaners. Not much else is known about him. Fig. 28 shows some of his designs.

Painter, Teague & Petertil was formed in 1950 by David Painter, James Teague, and Victor Petertil, all of whom worked together at Barnes & Reinecke. It lasted until 1960. They designed the case for the Regency TR-1 transistor radio, which sold 100,000 the first year. The TR-1 was selected by the Museum of Modern Art for the American Art and Design Exhibition in Paris in 1955. Fig. 29 shows the Regency radio and two patents for the housing taken out by their third partner, Victor Petertil.

David L. Painter was among the early students in the Industrial Design program at the School of the Art Institute of Chicago, enrolling in 1933 and receiving his diploma in 1936. Painter was vice president in charge of design at the Chicago design firm of Barnes & Reinecke, later becoming co-head of the product styling division. After 1960, Painter worked independently and in other partnerships. His work has been exhibited at the Museum of Modern Art, New York, the Smithsonian, and the Brooklyn Museum of Art.[38]

James Teague (1919–1996). James Teague studied industrial design at the School of the Art Institute of Chicago during the 1930s. Teague practiced product and graphic design independently in Chicago after 1960.[39]

Victor Petertil (1901–1995). Very little is known about him other than his association with his co-partners. He applied for the design patent for the Regency TR-1 in spite of the fact that he was only partly responsible for it.

Marlan H. Polhemus (1932–2017) worked for Harley Earl from 1957–1959; associate designer, Chapman Goldsmith Yamasaki, Chicago, (1959–1970); and became a full partner at Goldsmith Yamasaki Specht from 1970–1991. The Playmate Igloo cooler was one of Marlan's famous designs. Marlan was hired as a consultant by RCA to design radios in the 1960s–70s.[40] Some of his classic designs are shown in Fig. 30.

Carl Reynolds Jr. (1912–1990) worked at Chrysler as chief of interior design under Virgil Exner in the 1950s.[41] Later he moved on to work with J. M. Little & Associates designing radios for Crosley/Avco. Fig. 31 shows some of his Crosley radios which all have an automotive style to them, which reflects Carl's earlier work.

Jan Streng (1897–1968) designed radio cabinets for Pilot and Emerson. Later he worked for Remington Rand where he designed electric shavers and adding machine cases. Not much else is known about his career. Fig. 32 shows a few of his Bakelite cabinet designs for Emerson, Colonial, and Pilot. His radio cabinet designs for Emerson and Pilot are strikingly similar, although the Pilot radio was much larger. At the time it was the largest mold ever created.

Company Employee designers

Emil Harman (1897–1982) was born in Germany and immigrated to the United States after the devastation of World War I. He started working for the Automobile Radio Company, which made automobile radios under the Transitone banner. After Philco bought the company in late 1930, they became Philco's Transitone Division, and Emil's genius became readily apparent. He designed the cabinetry for many of Philco's most iconic products, such as the Safari transistorized TV, the "Briefcase portable TV," the 1946 slide-in phonograph (model 1201), and TP-10, among many others.[42] Fig. 33 shows just a sampling of his creativity.

Richard C. Marholz (1909–1961) and Louis J. Wronke (1906–1981) were in-house designers for the Belmont Corporation. Later, Belmont was purchased by Raytheon, and Marholz designed a few television cabinets for them. Louis Wronke went on to design work for Hallicrafters. Fig. 34 shows some of their designs.

International Designer

Wells Coates (1895–1958) was an English architect and industrial designer, one of the first practitioners of modernism in Great Britain. Coates was born in Japan and studied engineering at McGill University in Canada. In 1929 he moved to London where he studied architecture. In 1931 he co-founded Isokon with Jack Pritchard to manufacture furniture and other products of modern design in plywood. As an industrial designer, he became known for furniture design using tubular steel and plywood in the Bauhaus style. He was also the designer of a variety of BBC radio studio interiors, and of aircraft interiors for British Overseas Airways Corporation.[43]

Wells entered a design contest that was held by EKCO Radio Company and his entry became the winner. A total of five models of the EKCO radio were designed by Wells from 1934–1945, and they are shown in Fig. 35. His original design called for the radio to lay on its back with the controls facing up, but thankfully, EKCO had his design modified so that it would be used in an upright stance.[44]

Radio That Charms

Elsie de Wolfe

Miss de Wolfe, who has achieved a unique position in the world of art as an interior decorator, is designing for Kolster Radio a number of fine period cabinets.

The Kolster Eight pictured above is one of four beautiful models, of which there are two Eights and two Sixes. Each is housed in a cabinet of rare charm, designed by leading authorities. A Kolster is a pleasure to the eye as well as to the ear.

Both Ear and Eye

Kolster Radio brings a new and rare combination of perfected reproduction and fine cabinet work

F. A. Kolster and Elsie de Wolfe collaborate

KOLSTER Radio owes its hidden magic to the many achievements of F. A. Kolster, the noted scientist.

His accomplishments in tonal perfection are the sensation of the radio world.

Kolster Radio owes its exterior charm to Miss Elsie de Wolfe, the world's foremost authority on furniture and related decorations.

Her masterly knowledge brings to every home possessing a Kolster a piece of furniture of harmonious beauty.

Thus the F. T. C. Organization, pioneers in radio development, gives the public the very ultimate in radio enjoyment.

A set which delights the eye as well as the ear!

A set so simple to operate! No dials. Just turn from one station to another by name.

A single control. No charting of complicated numbers.

Full, rich, natural reproduction. Amazing clarity. The hitherto "Lost Chords" now developed—rich, clear.

All the delicate shadings, the individuality of musician or speaker—*actuality!*

No muffling. No interference. No exaggerations or repressions.

A Kolster neither adds to nor subtracts from broadcasting.

Vivid. Lifelike. A surprising thrill awaits you.

Hear this final-type radio in your own home or at a Kolster dealer's shop.

Learn how Kolster Radio differs from anything you've heard or seen before.

Then, like others of discrimination, you'll appreciate the efforts of the F. T. C. Organization in giving you the genius of F. A. Kolster, Elsie de Wolfe and other authorities. De luxe radio at everyday prices.

FEDERAL TELEGRAPH COMPANY
(of California)
Woolworth Building, New York City

F. A. Kolster

For eight years he was head of the Radio Section of the United States Bureau of Standards. He is now Chief Research Engineer of the F. T. C. Organization.

A Parade of Stations

One station after another parades by as you turn the Kolster regulator. No meaningless combination of numbers, but the actual names of the stations.

Whatever is on the air comes in easily, perfectly.

To play a Kolster is easier than playing a phonograph.

KOLSTER RADIO

Fig. 1. Kolster ad. (*Saturday Evening Post*, November 28, 1925, pp. 114–115)

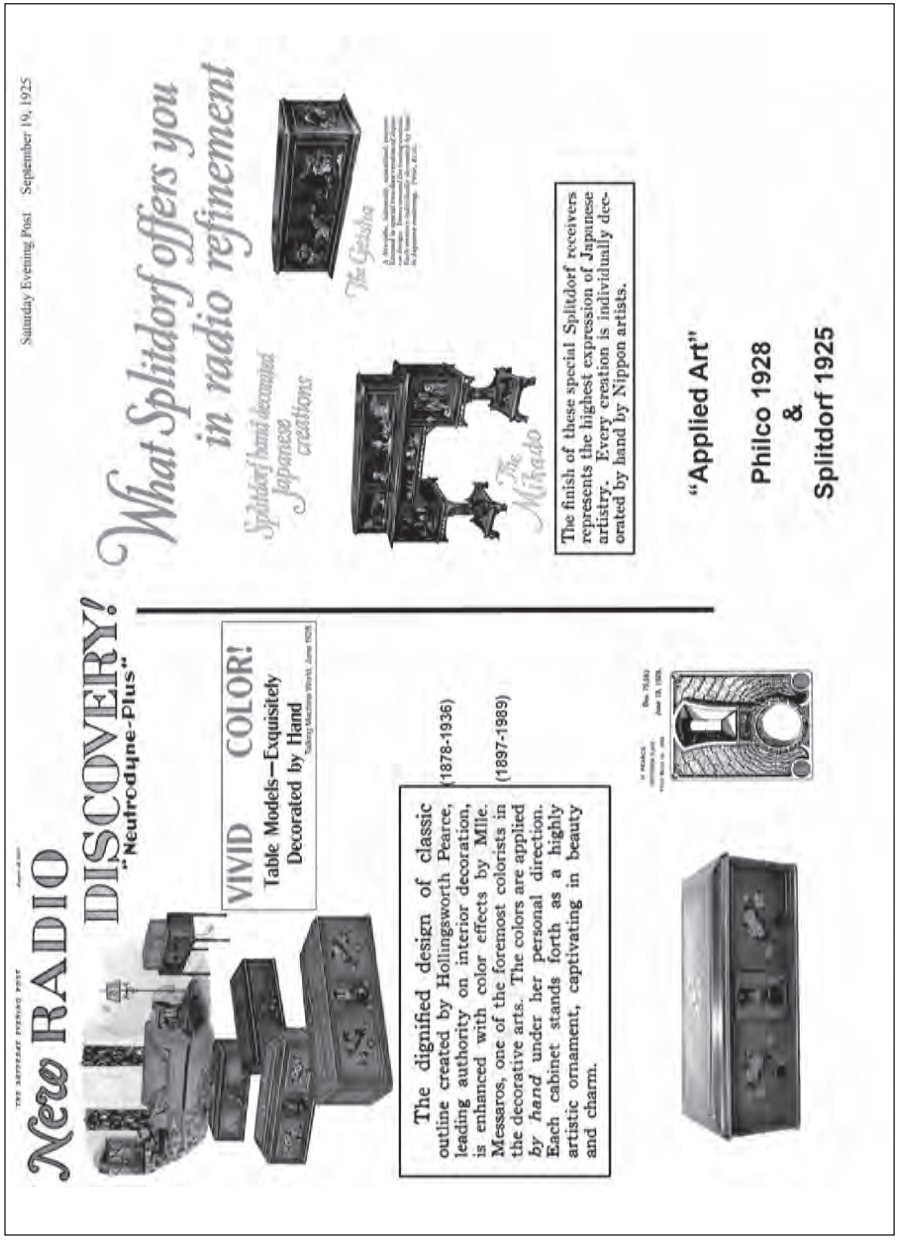

Saturday Evening Post September 19, 1925
New RADIO DISCOVERY!
"Neutrodyne-Plus"
VIVID COLOR!
Table Models—Exquisitely Decorated by Hand
What Splitdorf offers you in radio refinement
Splitdorf hand decorated Japanese creations
The Geisha
The Mikado
The dignified design of classic outline created by Hollingsworth Pearce, (1878-1936) leading authority on interior decoration, is enhanced with color effects by Mlle. Messaros, one of the foremost colorists in the decorative arts. The colors are applied (1897-1989) by hand under her personal direction. Each cabinet stands forth as a highly artistic ornament, captivating in beauty and charm.
The finish of these special Splitdorf receivers represents the highest expression of Japanese artistry. Every creation is individually decorated by hand by Nippon artists.
"Applied Art"
Philco 1928
&
Splitdorf 1925

Fig. 2. Philco ad. (*Saturday Evening Post,* August 18, 1928, pp. 118–119); Splitdorf ad. (*Saturday Evening Post*, September 19, 1925, pp. 178–179)

Men's Prize-Winning Entries in the $1000 Ideal Set Contest

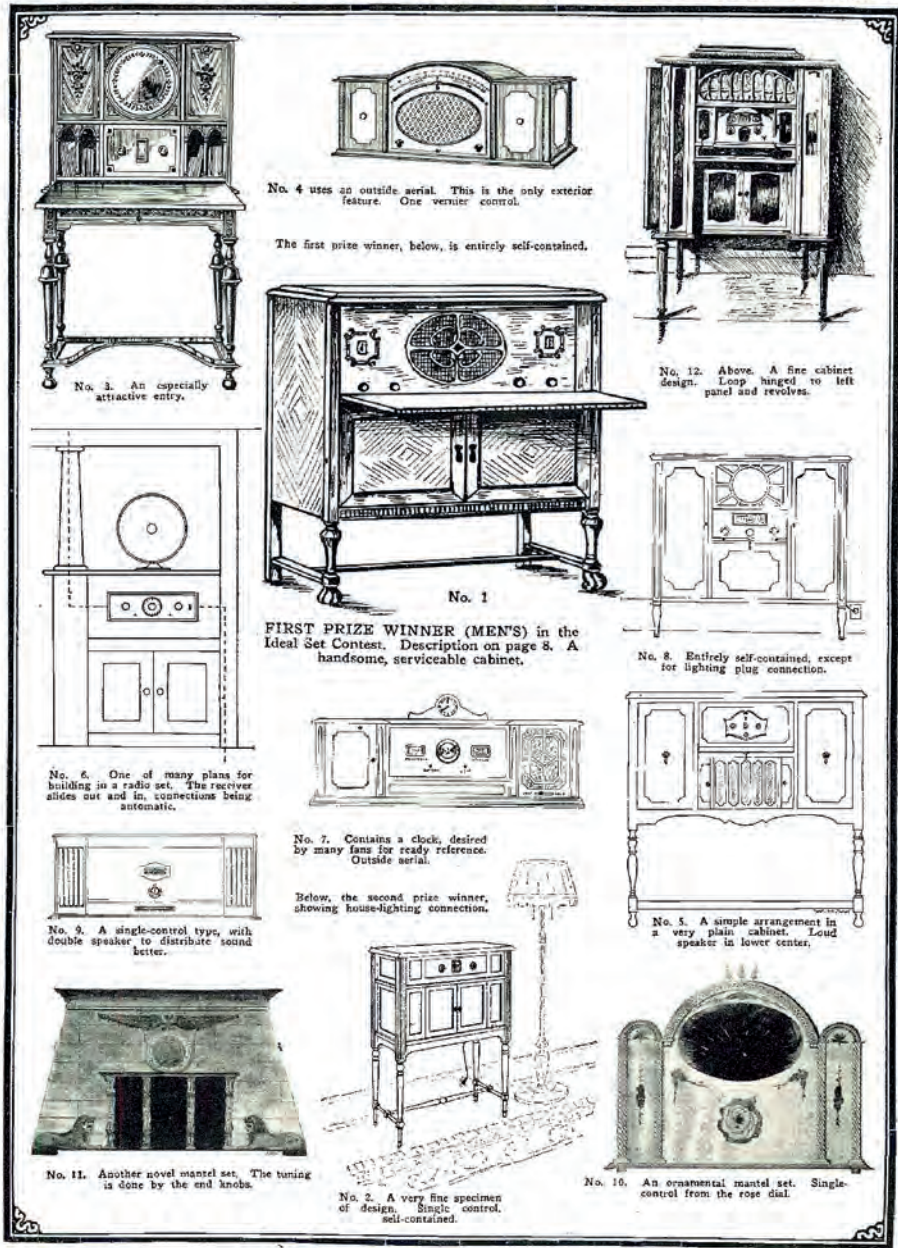

No. 4 uses an outside aerial. This is the only exterior feature. One vernier control.
The first prize winner, below, is entirely self-contained.
No. 3. An especially attractive entry.
No. 12. Above. A fine cabinet design. Loop hinged to left panel and revolves.
No. 1
FIRST PRIZE WINNER (MEN'S) in the Ideal Set Contest. Description on page 8. A handsome, serviceable cabinet.
No. 8. Entirely self-contained, except for lighting plug connection.
No. 6. One of many plans for building in a radio set. The receiver slides out and in, connections being automatic.
No. 7. Contains a clock, desired by many fans for ready reference. Outside aerial.
No. 5. A simple arrangement in a very plain cabinet. Loud speaker in lower center.
No. 9. A single-control type, with double speaker to distribute sound better.
Below, the second prize winner, showing house-lighting connection.
No. 11. Another novel mantel set. The tuning is done by the end knobs.
No. 2. A very fine specimen of design. Single control, self-contained.
No. 10. An ornamental mantel set. Single-control from the rose dial.

Fig. 3. Men's Ideal Radio Contest Winners. (*Radio News*, July 1926, p. 9)

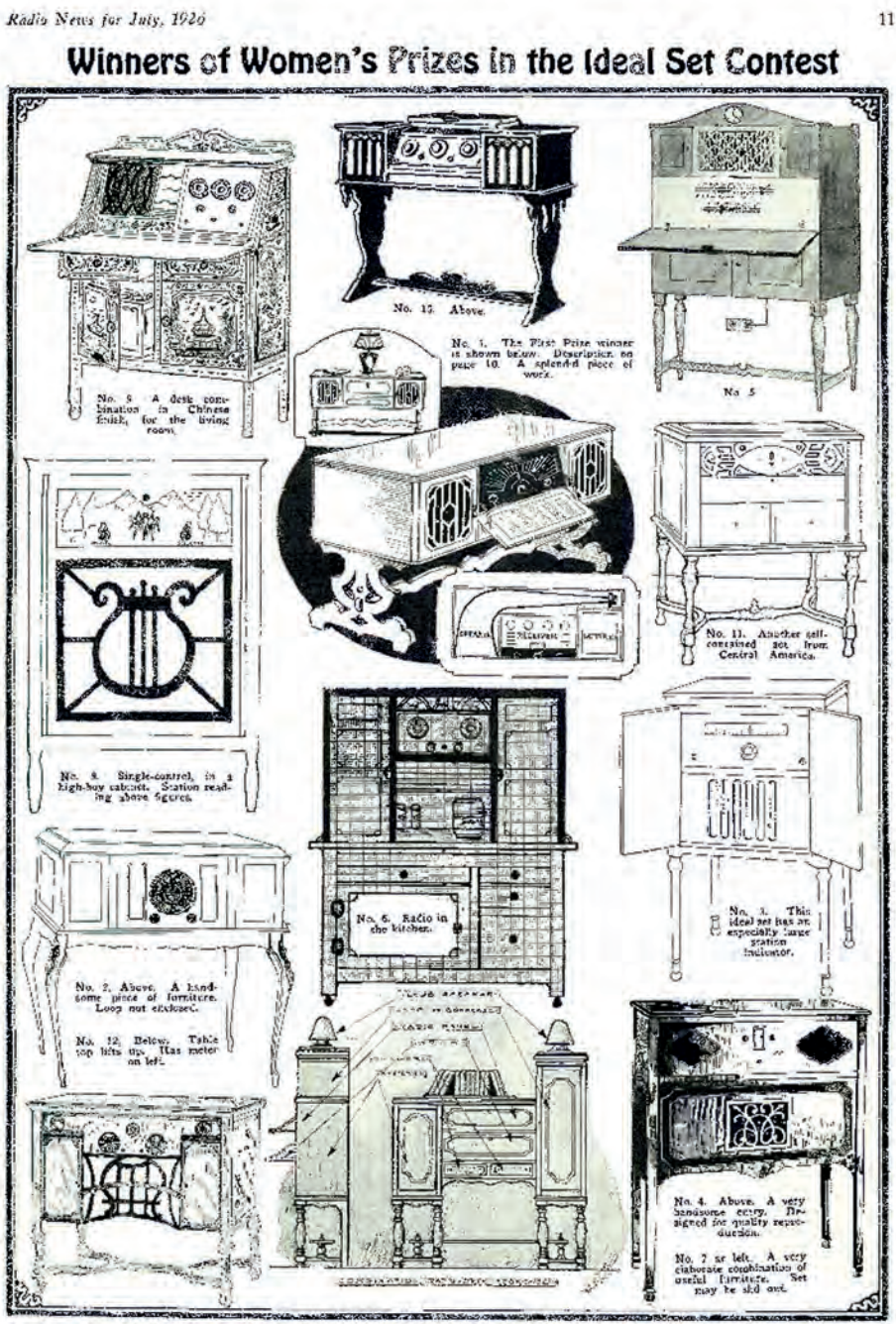

Radio News for July, 1926
11
Winners of Women's Prizes in the Ideal Set Contest
No. 13. Above.
No. 1. The First Prize winner is shown below. Description on page 10. A splendid piece of work.
No. 5
No. 8. A desk combination in Chinese Ebiik, for the living room.
No. 11. Another self-contained set from Central America.
No. 9. Single-control, in a high-boy cabinet. Station reading above figures.
No. 6. Radio in the kitchen.
No. 3. This ideal set has an especially large station indicator.
No. 2. Above. A handsome piece of furniture. Loop not enclosed.
No. 12. Below. Table top lifts up. Has meter on left.
No. 4. Above. A very handsome cecry. Designed for quality reproduction.
No. 7 at left. A very elaborate combination of useful furniture. Set may be slid out.

Fig. 4. Women's Ideal Radio Contest Winners. (*Radio News*, July 1926, p. 11)

Starting Today!

Westinghouse Radio $10,000 Idea Contest

1st PRIZE—

A $5,000 trip to Europe with all expenses paid . . . or $5,000 cash. Your cabin is ready—on a palatial ocean liner . . . any ship you choose. All for one idea!

THIS is an age of beauty . . . charm . . . style . . . good design even in the most utilitarian things. In fountain pens and beds, stoves and skyscrapers, radiators . . . and radios.

For example . . . the new Westinghouse Radio. Outward beauty to match their inward mechanical fineness. The beauty of ageless period design casing the newest radio marvel of this modern age. Westinghouse, who pioneered in radio since radio's very beginning, pioneers again, and ushers in the era of beautification in radio cabinets. Once a pioneer, always a pioneer!

In addition to its own efforts, Westinghouse invites yours. Invites all America to join its cabinet designing staff—its "Idea Department." And opens a nation-wide suggestion box and a bulletin of rich prizes, $10,625 in cash to stimulate your ideas.

Have you ever, in a casual evening's conversation, said—"I wonder why some radio manufacturer hasn't done this thing or that?" Tell the idea to Westinghouse—it may be a prize winner! Perhaps you have some basic idea for a radio cabinet's entire design. Tell Westinghouse! You don't need to make a drawing of your idea—just describe it in your own words. Some perfectly simple idea may be simply perfect . . . and may win you a trip to Europe or a $2,000 automobile or a sweet and unexpected sum to swell the balance in your bank-book.

2nd PRIZE—

A $2,000 automobile . . . any $2,000 car you choose. Or . . . the $2,000 in cash, if you prefer. Just for giving Westinghouse a cabinet idea.

WHAT DO WE MEAN "IDEAS"?
HERE'S A GOOD EXAMPLE
See these miniature models at your dealer's

One of the Westinghouse staff suggested this idea (it's not entered in the contest, of course, since Westinghouse employees are not eligible) but it furnishes a good example of the type of ideas we seek. These cabinets are lighted from within—and the light shines through the translucent panels at each side. In one cabinet the panels are rich, amber tone; in the other cabinet, the Gothic model, the panels are multi-colored and the effect suggests sunlight drifting through the stained glass windows of some mellow old cathedral. See them at your Westinghouse Radio dealer's because they might set your "thinking cap" buzzing with ideas of your own. Of course, these are only miniatures and have nothing to do with the new Westinghouse Radio sets now on sale at your dealer's.

3rd PRIZE—

$1,000 will be presented to the person who submits the third best radio cabinet idea. This check is waiting for the winner of the third prize.

HOW TO ENTER THE CONTEST

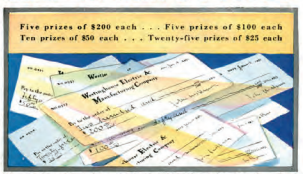
1. Contest opens September 25th and closes December 24th. Ideas must be in the mails before midnight December 24th. Winners will be announced January 19th.
2. Anyone may compete except employees of the Westinghouse Electric and Manufacturing Company or its associated companies.
3. Ideas may be submitted in writing. If sketches are submitted, explanatory letter must accompany them. You may submit as many ideas as you like, but each must be on a separate sheet of paper with your full name and address. No letters or sketches will be returned.
4. Prizes will be awarded to the best 48 original and acceptable ideas for beautifying radio cabinets. If a winning idea is submitted by more than one person the full prize will be awarded to each contestant.
5. All prize winning ideas become the property of the Westinghouse Electric and Manufacturing Company.
6. Leaflets giving helpful suggestions and Contest Entry Blanks can be had at any Westinghouse Radio dealer's store. Ideas must be mailed to Westinghouse Electric and Manufacturing Company, Radio Department, 150 Broadway, New York City.

The judges of the contest are:

MISS HELEN KOUES, Director of Good Housekeeping Studio.
MISS NEYSA MCMEIN, famous artist.
MISS ROSAMOND PINCHOT, prominent member of younger set.
RAYMOND LOEWY, famed Parisian artist and designer.
E. B. INGRAHAM, Vice-President, Times Appliance Co., Inc., New York City.
A. W. ROBERTSON, Chairman of the Board, Westinghouse Electric and Manufacturing Company.

9-417

and 45 More Prizes



One nice thing about this contest is that it isn't limited to just a few prizes. Even if you don't win a big prize you still have a chance for a check.

Go to your Westinghouse Radio dealer today and enter the contest. See models of the miniature lighted cabinets . . . Get full information . . . Win a prize!

Westinghouse Radio

A NINE TUBE, SCREEN-GRID SUPER-HETERODYNE

Four sets, including a radio phonograph combination. Remote control (on larger models). Four screen-grid tubes . . . Tone control (on larger models) . . . Push-pull power amplifier . . . Improved power filter system no "hum" . . . New electrodynamic power speaker . . . Local-distant switch. See and hear these new sets at your Westinghouse Radio dealer's and let him explain the convenient time payments.

WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY
RADIO DEPARTMENT . . . 150 BROADWAY, NEW YORK CITY

THE PIONEER OF RADIO IN THE HOME

© W. E. & M. Co. 1930

Fig. 5. Westinghouse ad. (*Saturday Evening Post*, September 27, 1930, pp. 68–69)

Comparisons of a Few Leading Industrial Designers†

	AGE	YEARS AS INDUSTRIAL DESIGNER	PREVIOUS EXPERIENCE	COMPENSATION *(royalties are subject to special arrangements)*	STAFF MEMBERS
Dreyfuss	29	5	Theatre sets	Flat fee: $1,000 to $25,000. Hourly consultation: $50	5
Geddes	40	7	Theatre sets and costumes	Flat fee: $1,000 to $100,000. Royalties	30
Guild	35	10	Art director Furniture expert	Retainer fee up to $25,000. Fee per day: $100 to $200. Flat fee: $300 to $25,000 Royalties	4
Loewy	40	6	Electrical engineer Free-lance advertising	Retainer fee: $10,000 to $60,000. Flat fee: $3,000 up. Royalties	1
Teague	48	6	Advertising designer	Retainer fee: $12,000 to $24,000. Flat fees: $500 to $10,000	4
Van Doren	38	4	Painter Ghost writer	Consultation fee: $100 per day. Jobs executed: $500 to $5,000	8
Vassos	35	7	Advertising agency Illustrator	Retainer fee: $12,000. Flat fee: $1,000 to $7,000	3

†*This list does not pretend to cover the field of industrial design; it merely presents ten designers chosen arbitrarily as typical and illustrative.*

Fig. 6. Comparison of industrial designers fees. (*Fortune*, February 1934)

Fig. 7. Collage of Bakelite ads. (*Electronics*, October 1935, p. 1; January 1934, p. 7; March 1936, p. 35; May 1936, p. 1; August 1936, p. 33; September 1937, p. 45)

Fig. 8. USPS stamps honoring industrial designers. (USPS Scott # 4546: Pioneers of Industrial Design, 44 cent forever stamps; USPS Scott # 4333: Charles and Ray Eames, 42 cents)

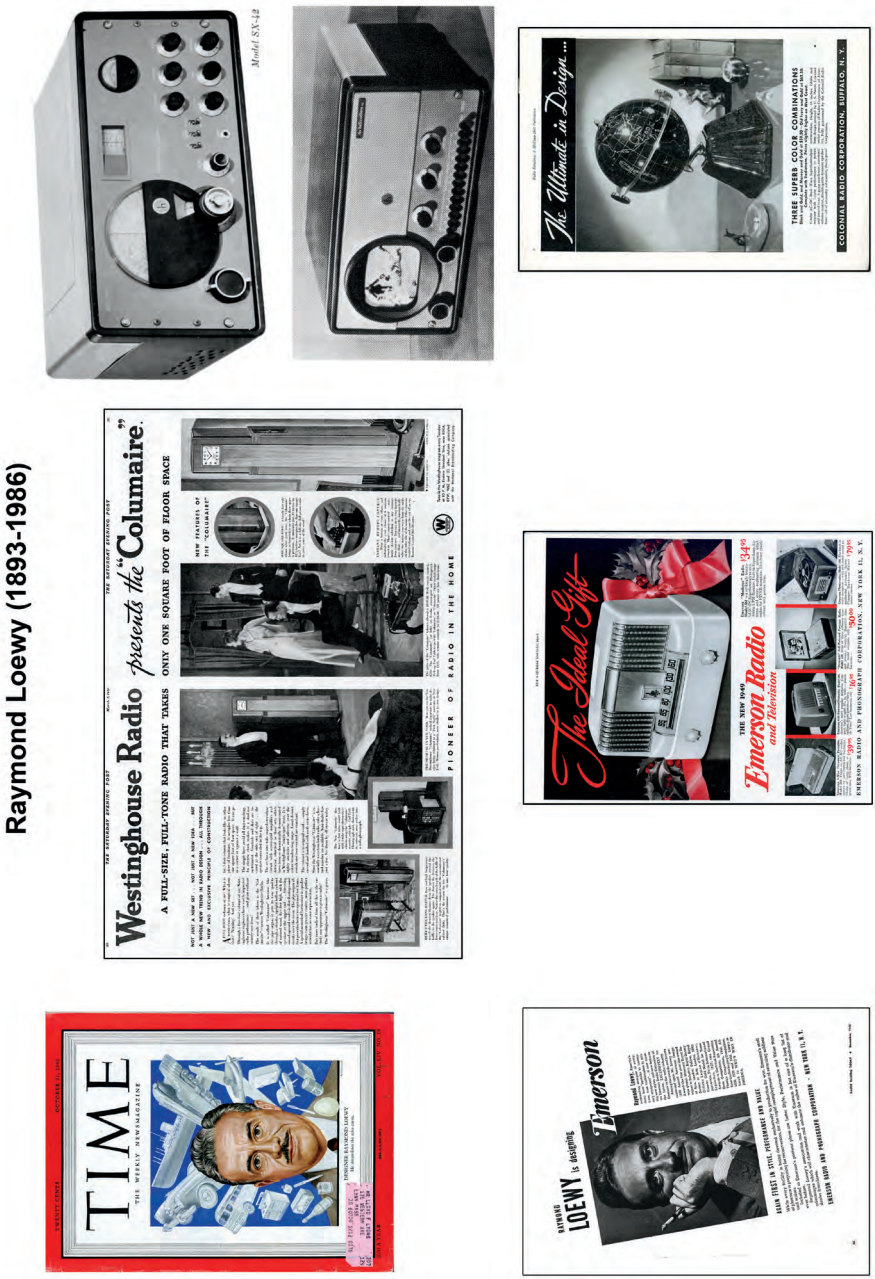

Raymond Loewy (1893-1986)
Model SX-42
The Ultimate in Design...
THREE SUPERB COLOR COMBINATIONS
COLONIAL RADIO CORPORATION, BUFFALO, N. Y.
TIME
THE WEEKLY NEWSMAGAZINE
Westinghouse Radio presents the "Columaire."
A FULL-SIZE, FULL-TONE RADIO THAT TAKES ONLY ONE SQUARE FOOT OF FLOOR SPACE
PIONEER OF RADIO IN THE HOME
The Ideal Gift
THE NEW 1949
Emerson Radio and Television
RAYMOND LOEWY is designing Emerson

Fig. 9. Some of Raymond Loewy's radio designs. (*Time*, October 31, 1949, p. 1; *Saturday Evening Post*, March 7, 1931, pp. 58–59; *Radio & Television Retailing*, December 1943, p. 12; *Saturday Evening Post*, December 4, 1948, p. 135; *Shaping America's Products*, 1956, pp. 46–49; *Hallicrafters Television Landmarks of 20th Century Design*, 1993, p. 161; *Radio Retailing*, November 1933, p. 6)

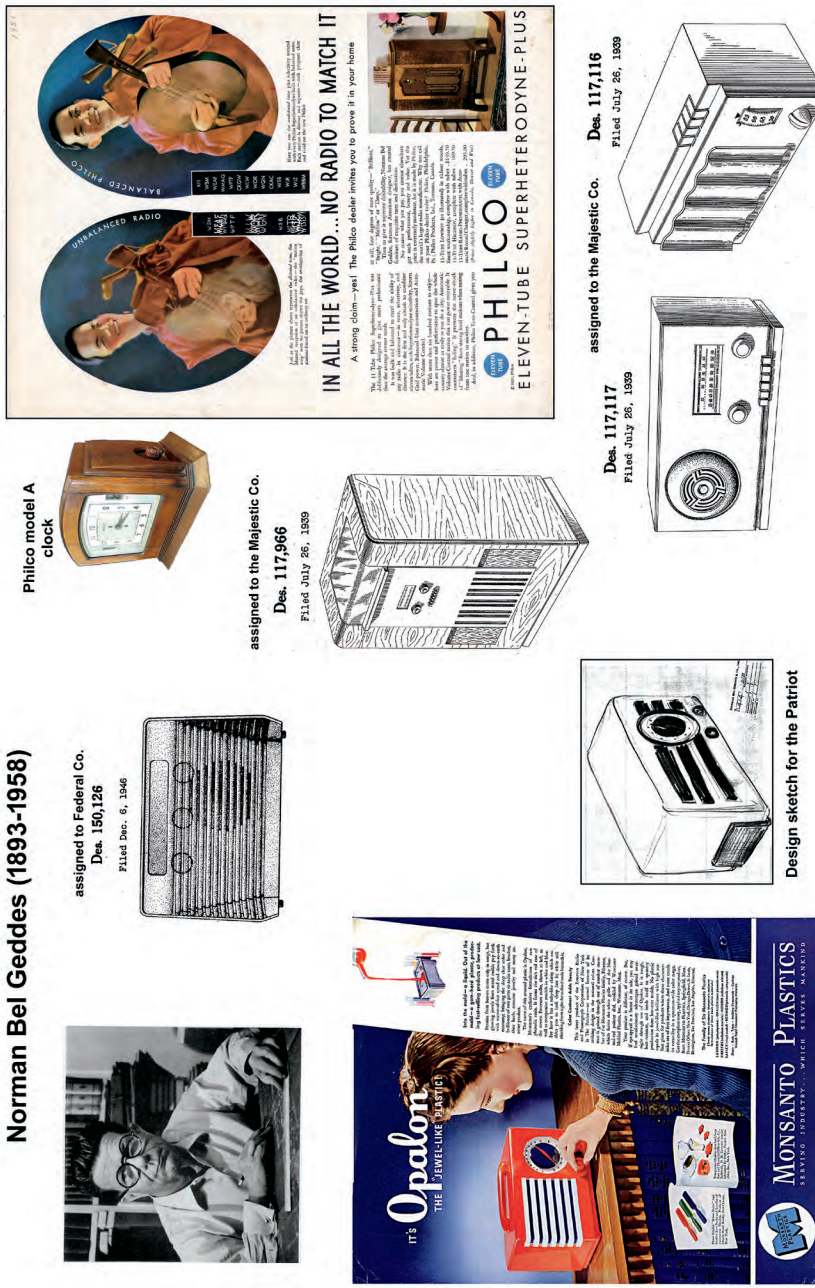


Fig. 10. Norman Bel Geddes collage of radios and design patents. (*Fortune*, July 1941; Patents numbers D150,126; D117,966; D117,116; D117,117; Philco Furniture History files at National Capitol Radio & TV Museum; *Saturday Evening Post*, September 26, 1931, p. 3; Files at Henry Ransom Center at U of Texas, Austin)

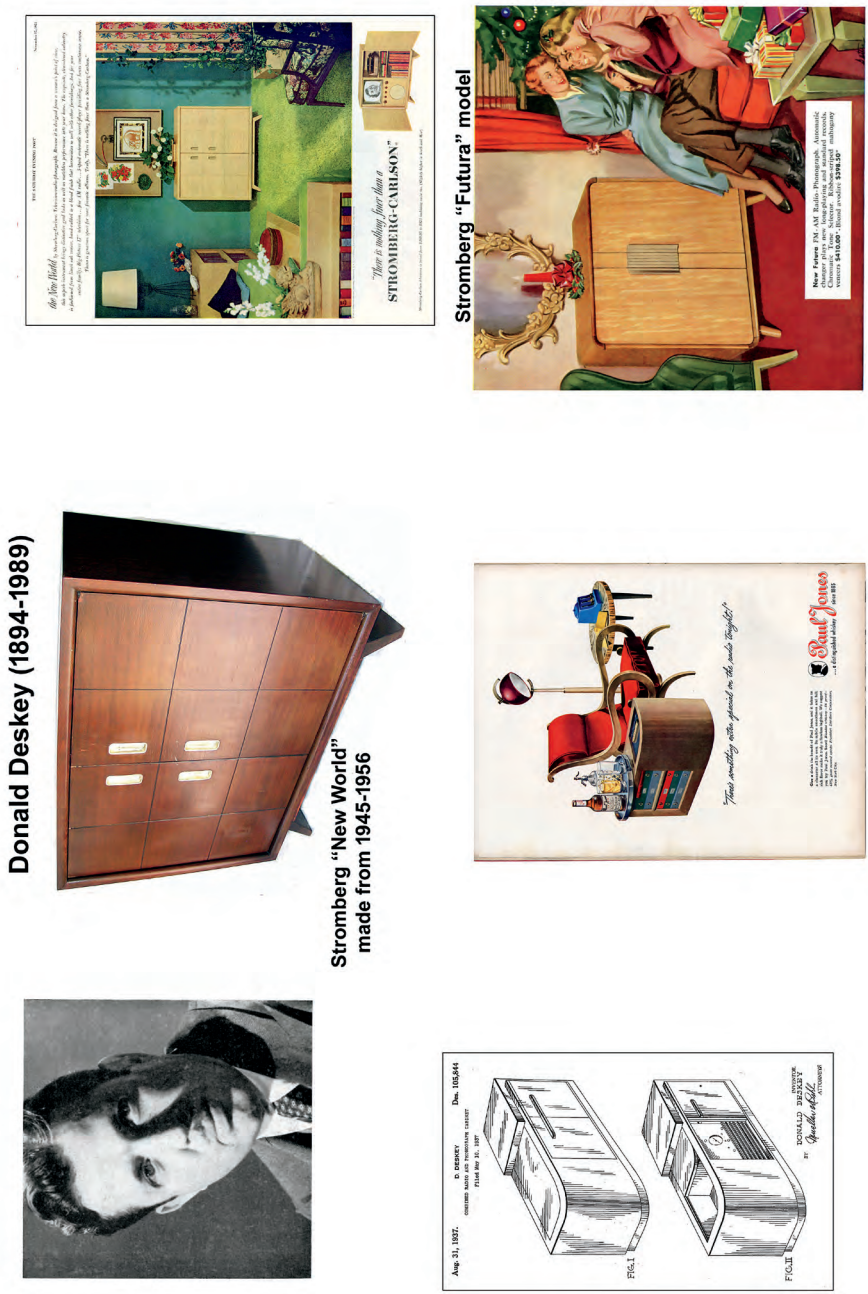


Fig. 11. Donald Deskey collage of radio designs. (*U.S. Industrial Design 1949–50*, p. 42; *Saturday Evening Post*, November 17, 1951, p. 16; Patent number D105,844; *Life*, February 5, 1945, p. 36; *Saturday Evening Post*, December 4, 1948, p. 101)

Fig. 12. Henry Dreyfuss collage of radio designs. (*Forbes*, May 1, 1951, p. 1; *Industrial Design in America: 1954*, p. 149; *U.S. Industrial Design Yearbook: 1949–50*, p. 43; *Life,* November 15, 1946, p. 77)

Fig. 13. Charles & Ray Eames collage of bent plywood designs for radios and chairs. (*Wall Street Journal*, May 28, 2015; *Eames Design: The Work of the Office of Charles and Ray Eames*, 1989)

Fig. 14. More designs from the Eames' as well as other radios inspired by them. (*Eames Design: The Work of the Office of Charles & Ray Eames*, 1989; *Radio & Television Journal*, July 1946, p. 35)

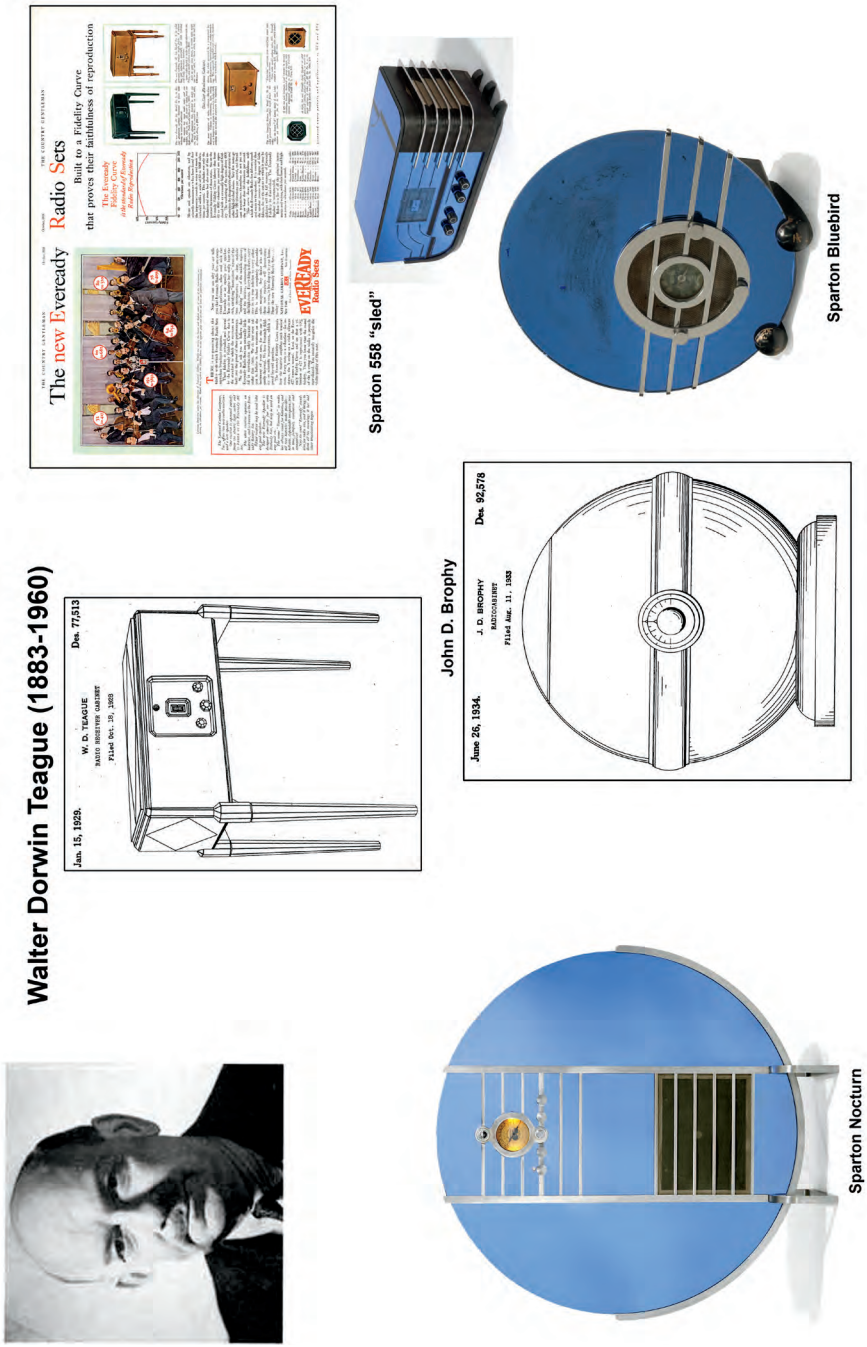


Fig. 15. Walter Dorwin Teague classic radio designs for Sparton and Eveready. (Files at Teague archives at Syracuse U; Patent numbers D77,513; D92,578; *The Country Gentleman*, October 1928)

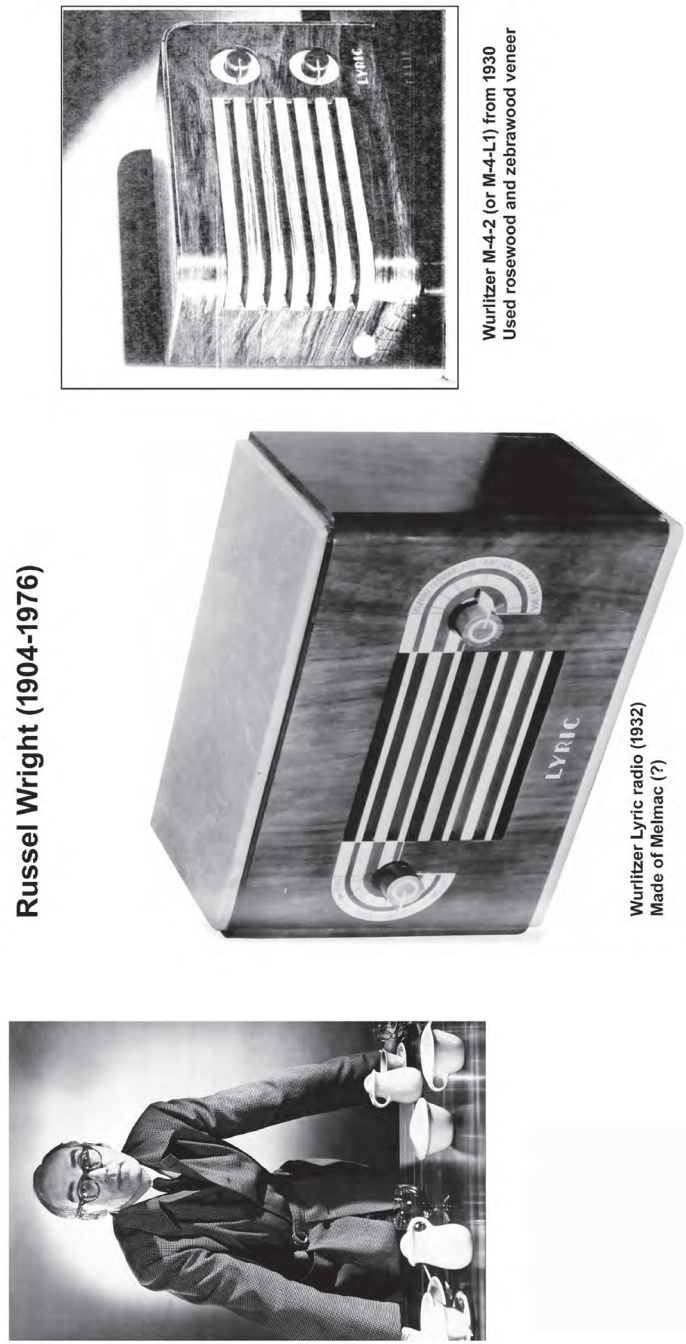


Fig. 16. Russel Wright table radio designs for Wurlitzer Lyric. (*Russel Wright: American Designer*, 1985, pp. 14, 29, 174)

Fig. 17. Jack Morgan radio designs for Sears & Roebuck. (Patent numbers D100,501; D134,707; D104,080; D123,839; D104,197; *Industrial Design in America: 1954*, p. 40; *Look*, 1952)

Fig. 18. Some of Ben Nash's radio designs for Philco. (Philco Furniture History files, 1928–49, at National Capitol Radio & TV Museum)

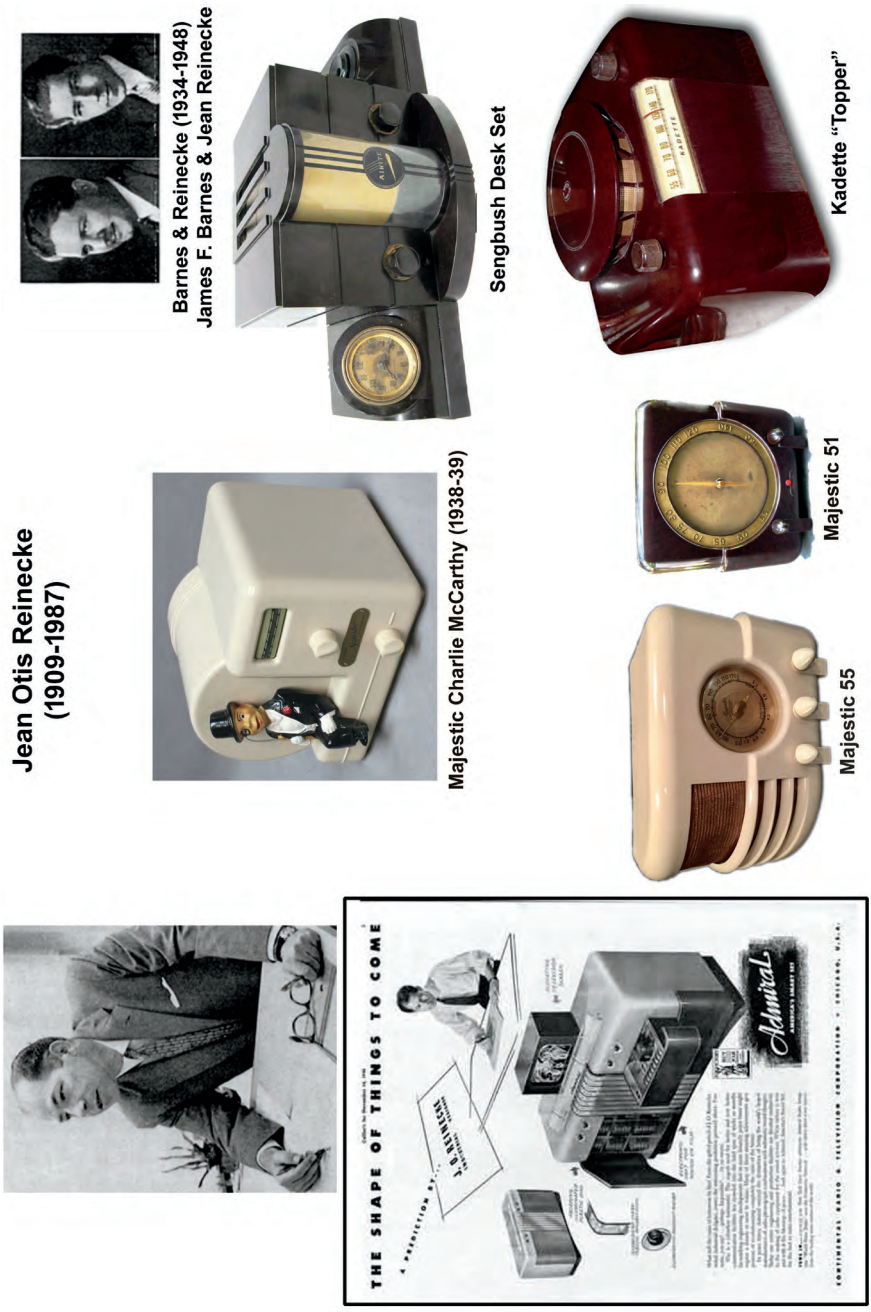


Fig. 19. Jean O. Reinecke and James F. Barnes' designs for Majestic and Sengbush. (*Colliers*, November 24, 1934, p. 3; Louise Reinecke collection, 1993; *Modern Plastics*, October 1937, p. 123; *Modern Plastics*, October 1940, p. 52)

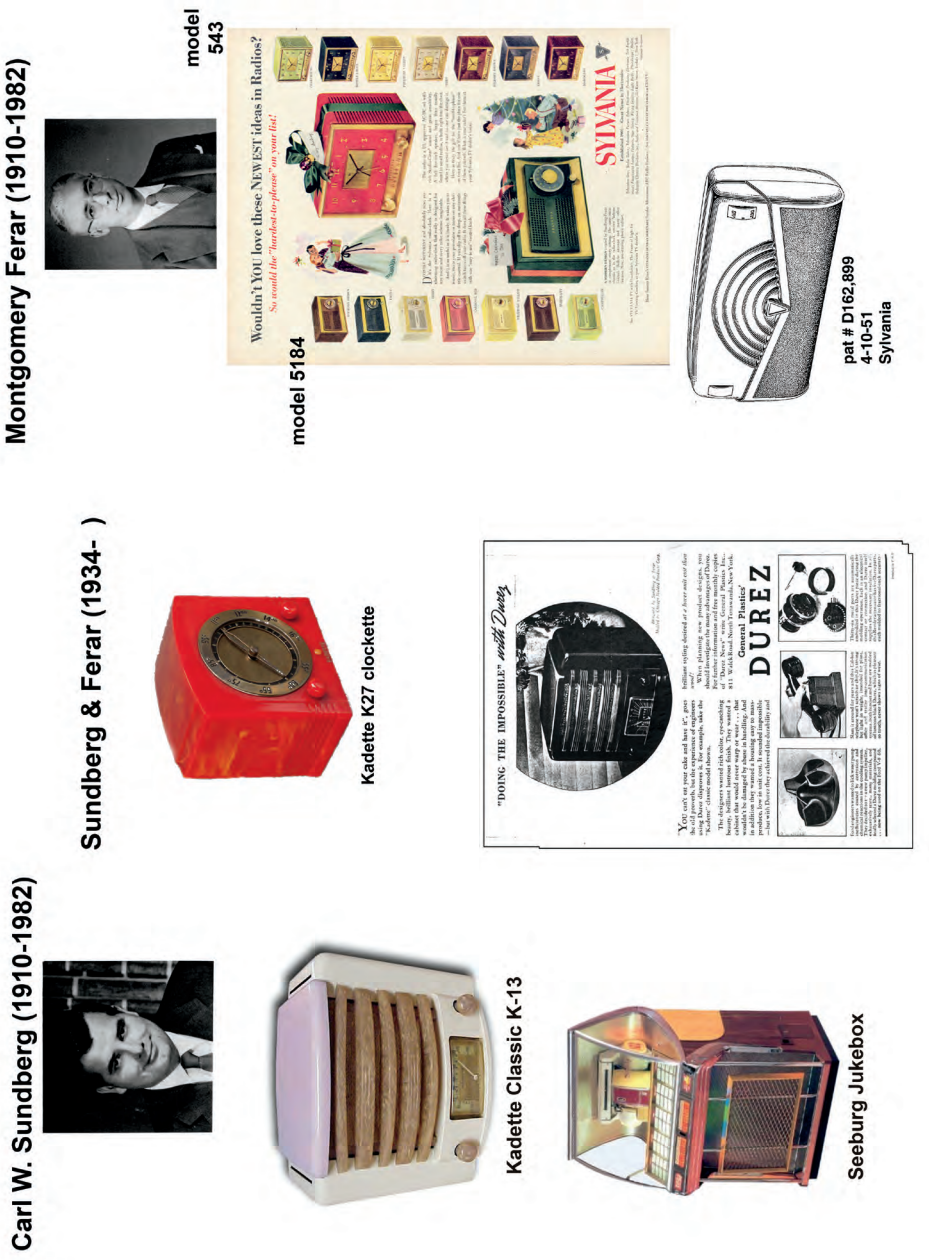


Fig. 20. Sundberg & Ferar's designs for the Kadette clockette plus designs for Sylvania and Seeburg. (Patent numbers D184,969; D162,899; D165,704; *Life*, November 26, 1951, p. 124; Sundberg & Ferar archives)

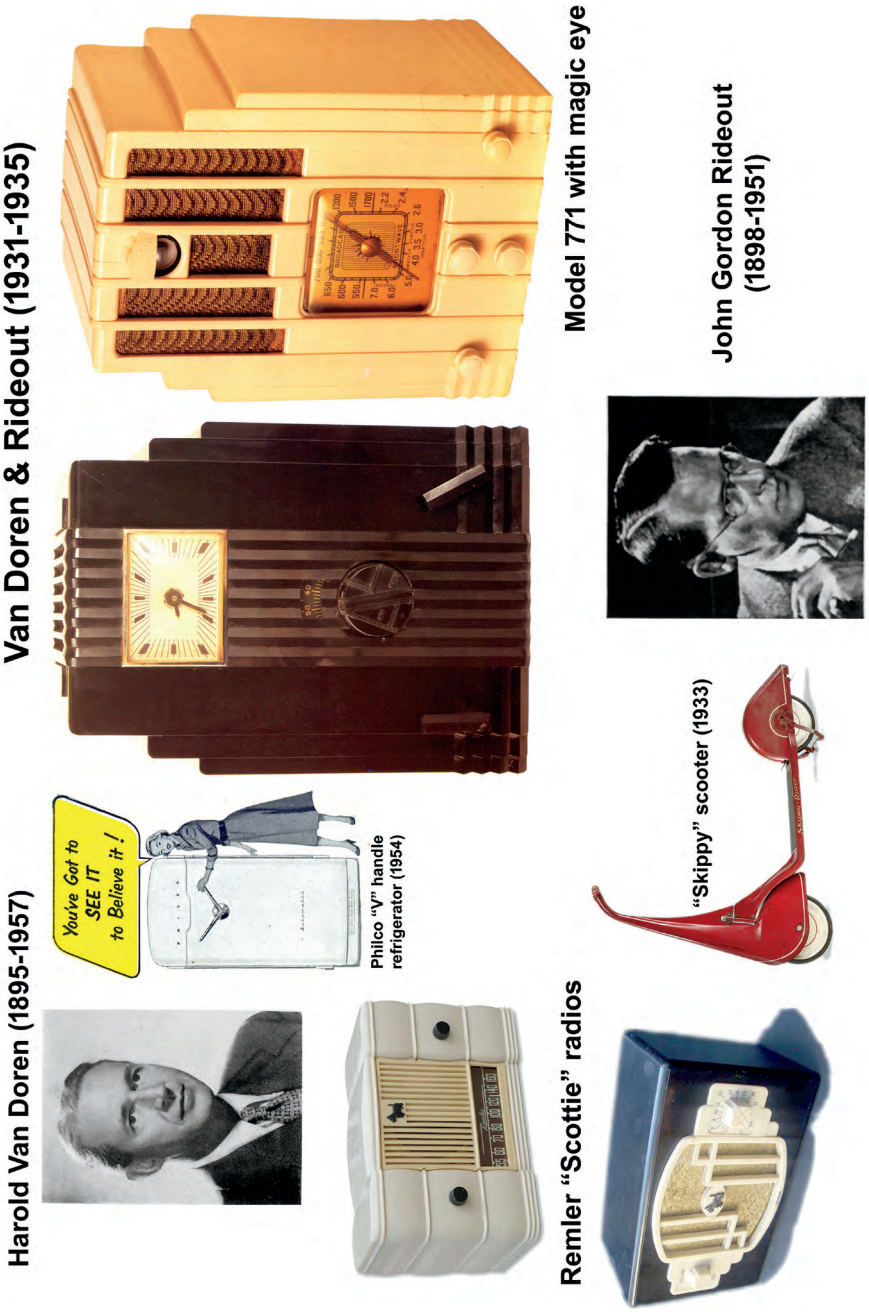

Harold Van Doren (1895-1957)
Van Doren & Rideout (1931-1935)
Model 771 with magic eye
John Gordon Rideout
(1898-1951)
You've Got to SEE IT to Believe it!
Philco "V" handle refrigerator (1954)
"Skippy" scooter (1933)
Remler "Scottie" radios

Fig. 21. Harold Van Doren and John Gordon Rideout's designs for Air King and Remler. (*Life*, May 24, 1954; *Industrial Plastics*, 1939, p. 295; Patent number D99,225; *Bakelite Radios*, 1996, pp. 78, 88)

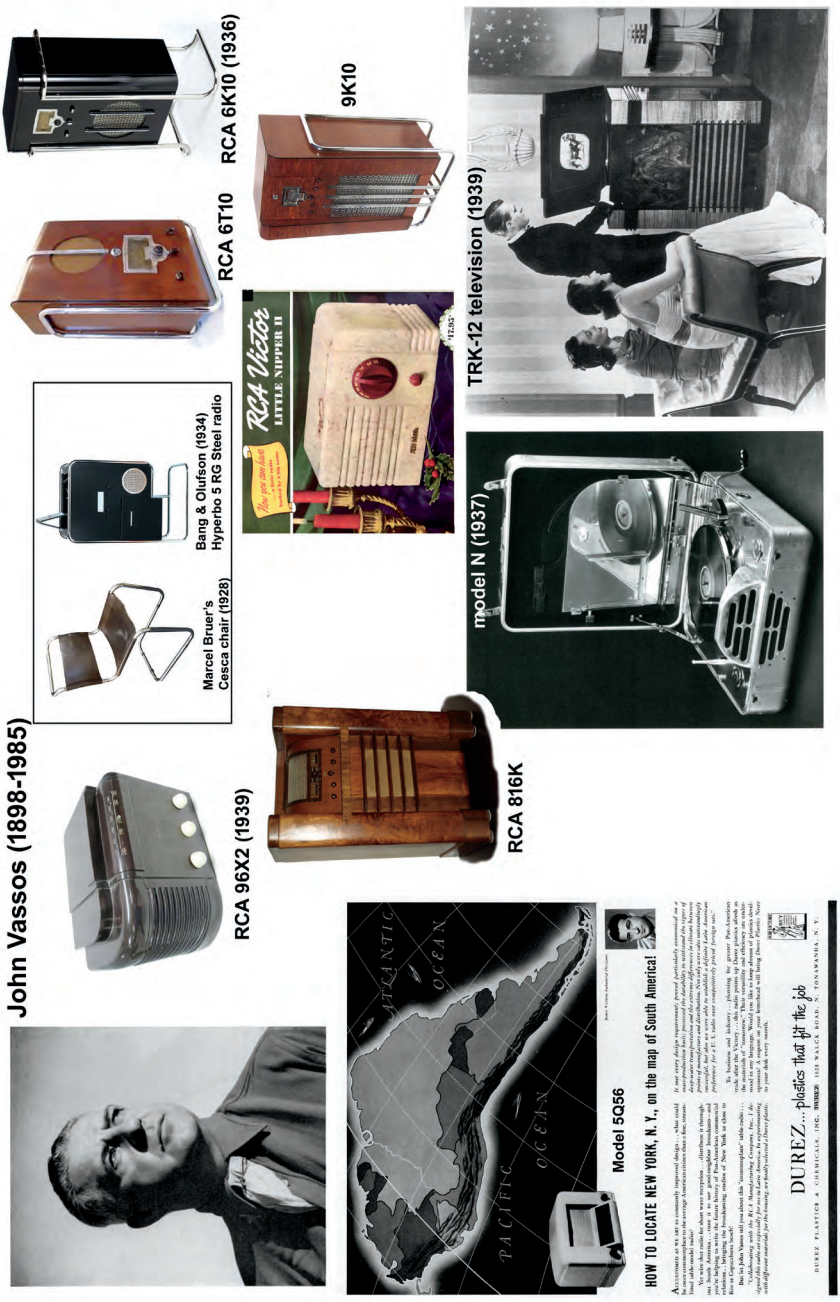


Fig. 22. John Vassos' designs for RCA. (*Fortune*, May 1942; *Saturday Evening Post*, December 17, 1938, p. 46; *John Vassos*: *Industrial Design for Modern Life*, Shapiro, 2016)

Fig. 23. George W. Walker's design for the Detrola Pee-Wee and a few escutcheons he created for Grigsby-Grunow. (*Time*, November 4, 1957, p. 1; *Fortune*, August 1942; Patent numbers D105,190; D105,174; D114,651; *Esquire*, October 1941)

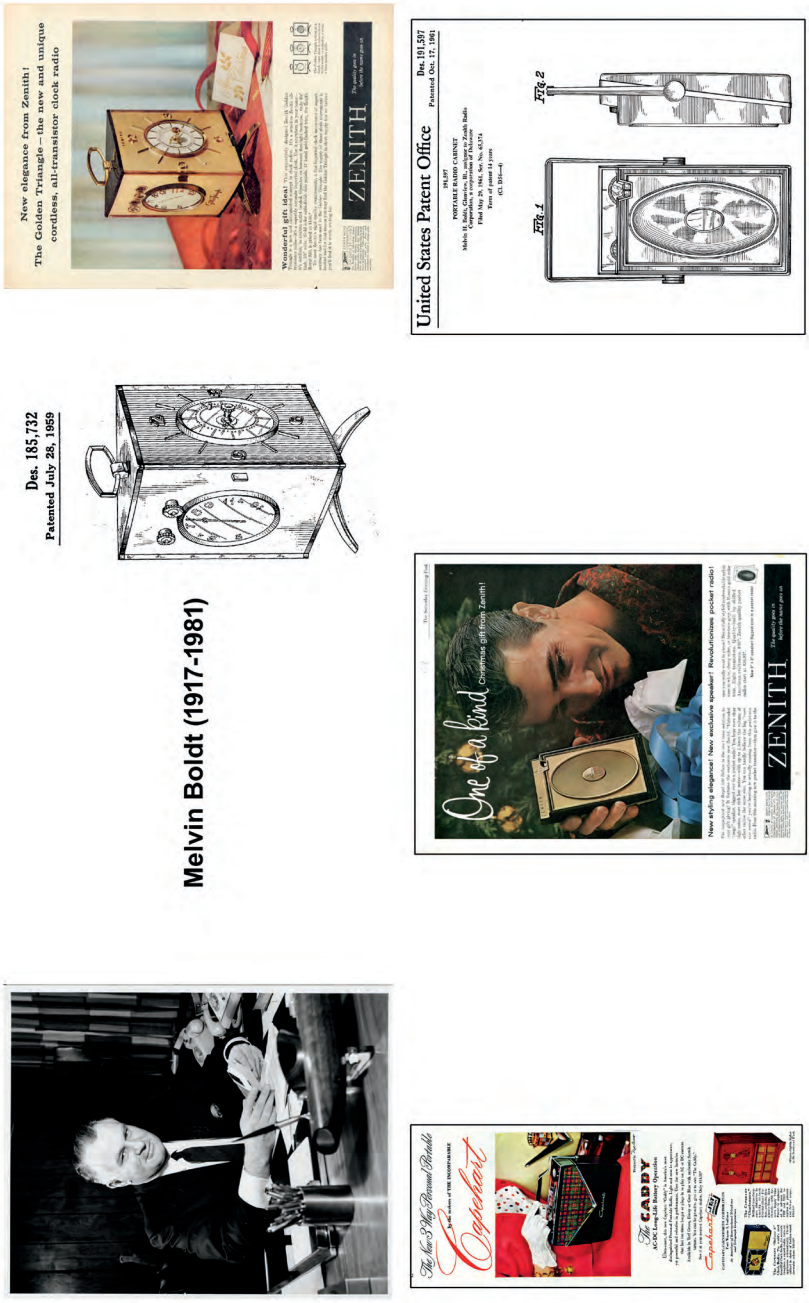


Fig. 24. A few of Mel Boldt's many designs for Zenith and Capehart. (*Saturday Evening Post*, May 23, 1953, p. 12; *Saturday Evening Post*, November 25, 1961; *Look*, late 1959; Patent numbers D185,732; D191,597)

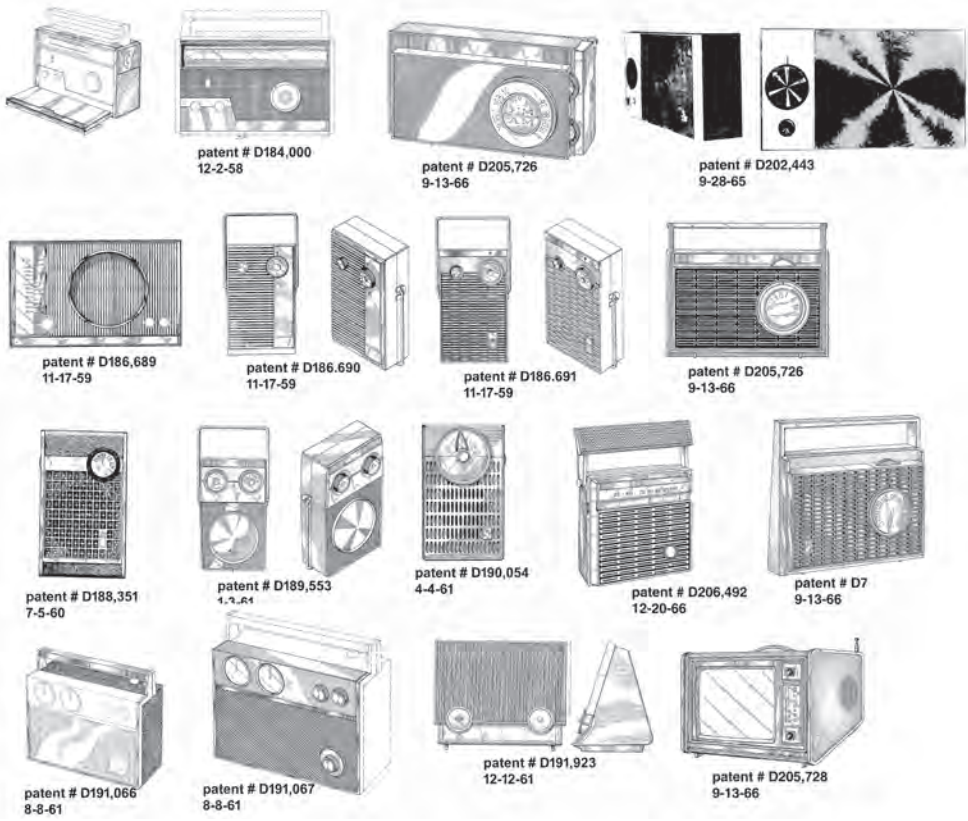


Fig. 25. More of Mel Boldt's Zenith designs. (Patent numbers D184,000; D205,726; D202,443; D186,689; D186,690; D186,691; D205,726; D188,351; D189,553; D190,054; D206,492; D191,066; D191,067; D191,923; D205,728)

Fig. 26. A few of Robert D. Budlong's radio designs for Zenith. (*Saturday Evening Post*, February 7, 1953, p. 68; June 25, 1949, p. 91; December 6, 1947, p. 7; Patent numbers: D85,027; D167,612; D167,613; D165,507; D167,615; D148,518; D163,678; D161,311; D150,925)

More than a portable...
More than a table model
Exciting new
dualette by SYLVANIA
Jon Hauser (1916-1999)
Motorola XC4GW
clock-radio
675 Sportster
T7 transistor
model B570 (1954)
The Philco you give will be the gift of the year.
And no wonder! Philco is the most preferred
name in radio today. Let your Philco dealer
help you pick the perfect gift for everyone
on your list right now!
Plays on regular flashlight batteries
Every part guaranteed 5 YEARS!
Tuck a superb-sounding transistor
radio in that Christmas stocking!
First and only radios with every part
GUARANTEED FIVE YEARS!
PHILCO Transistor Radios

Fig. 27. A few of Jon Hauser's radio and TV designs for Philco, Motorola and Sylvania. (*Life*, December 2, 1957, p. 4; January 12, 1958, p. 42; *Saturday Evening Post*, December 14, 1957, p. 3; Jon Hauser collection; *Industrial Design in America, 1954*, p. 40; *Holiday*, June 1956, p. 86; personal photo from Jon Hauser)

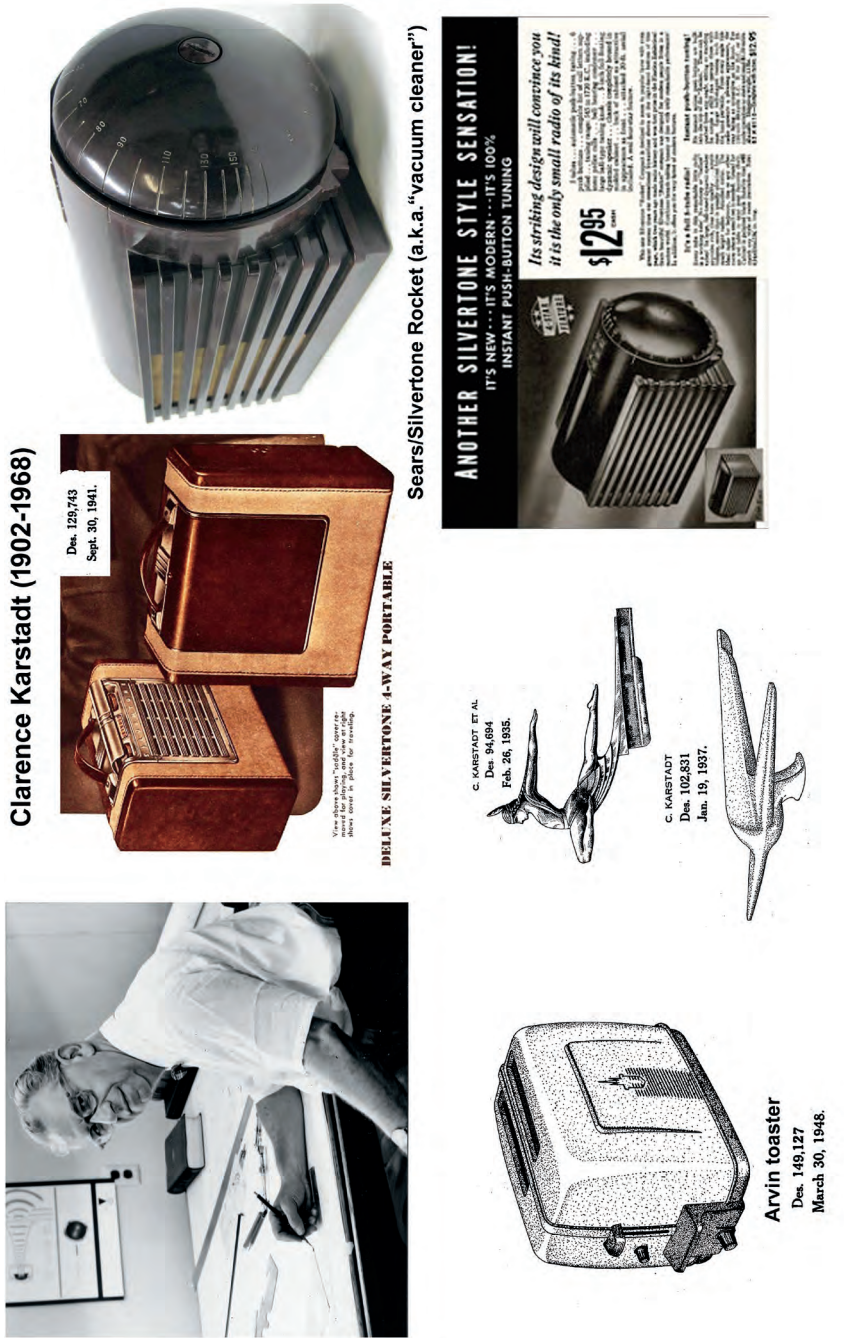


Fig. 28. Clarence Karstadt's radio designs for Sears, and a few other creations. (Patent numbers: D129,743; D149,127; D94,694; D102,831; Sears advertising brochure)

Fig. 29. Painter, Teague, and Petertil's design for the Regency TR-1. (Patent numbers: D176,480; D176,481; Regency advertising brochures)

Fig. 30. Marlan H. Polhemus' designs for RCA and the Playmate Igloo cooler. (Marlan Polhemus collection; *Founders of Industrial Design*, 2014, p. 168; *Look*, November 3, 1970, p. 87)

Carl Reynolds Jr. (1912-1990)
Series 11-120
Series 11-135
Decorator model 11-106
Crosley Riviera 11-301
model 11-100
CROSLEY 1951 COLOR-STYLED RADIOS
Sound as good as they look... and that's Wonderful!
CROSLEY RADIOS for Christmas
THE PACE-SETTING DESIGNS ARE COMING FROM CROSLEY!
May 29, 1934. C. J. KLEIN ET AL. Des. 92,358
AUTOMOBILE RADIATOR ORNAMENT OR SIMILAR ARTICLE
Filed Feb. 27, 1933

Fig. 31. Carl Reynolds' designs for Crosley/Avco. (*Life*, November 13, 1950, p. 21; Patent numbers: D160,537; D160,970; D160,538; D160,742; D160,740; D160,741)

Jan W. Streng (1897-1968)
The 1937 Pilot radio, 18-1/2 inches high, was the largest plastic radio cabinet made in that year. Designed by Jan Streng for the export market, it had a sturdy one piece molded case that alone weighed ten pounds and could, according to the manufacturer, withstand the weight of a man without breaking.
Colonial 300 (compact)
Pilot
Emerson
Styling Large Cabinets with Bakelite Molded...
BAKELITE
THE MATERIAL OF A THOUSAND USES
The Robot that had its face lifted
DUREZ... plastics that get the job

Fig. 32. Jan Streng's designs for Pilot, Colonial, and Emerson. (*Fortune*, October 1942; *Radio Engineering*, July 1933, pp. 9, 10; *Modern Plastics*, January 1936, p. 33ff; *Electronics*, February 1936; *Radio Retailing*, December 1937, p. 43)

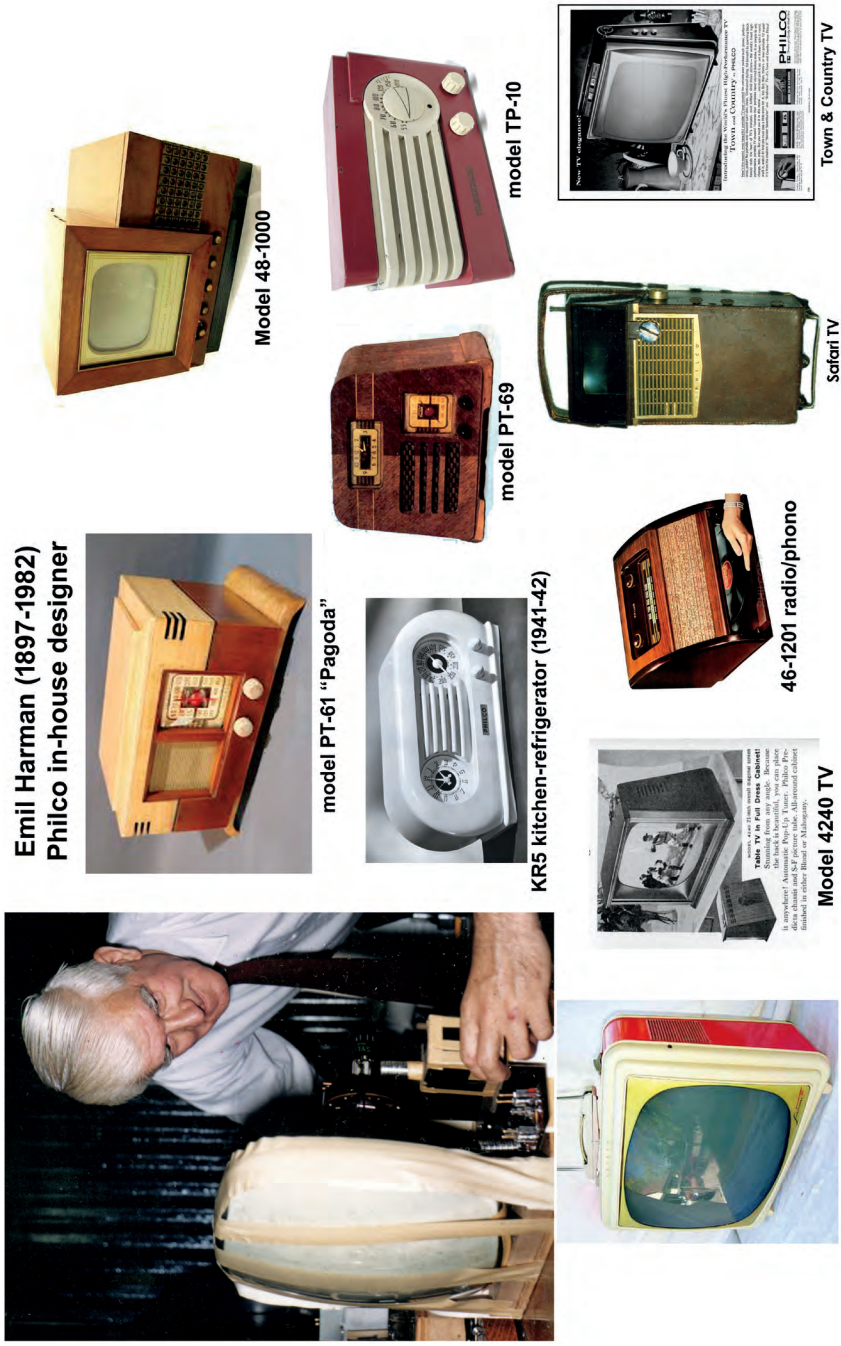


Fig. 33. Emil Harman's designs for Philco. (*Saturday Evening Post*, September 13, 1958, p. 73; *Life*, December 1, 1961, p. 129; Philco history files at National Capital Radio and TV Museum)

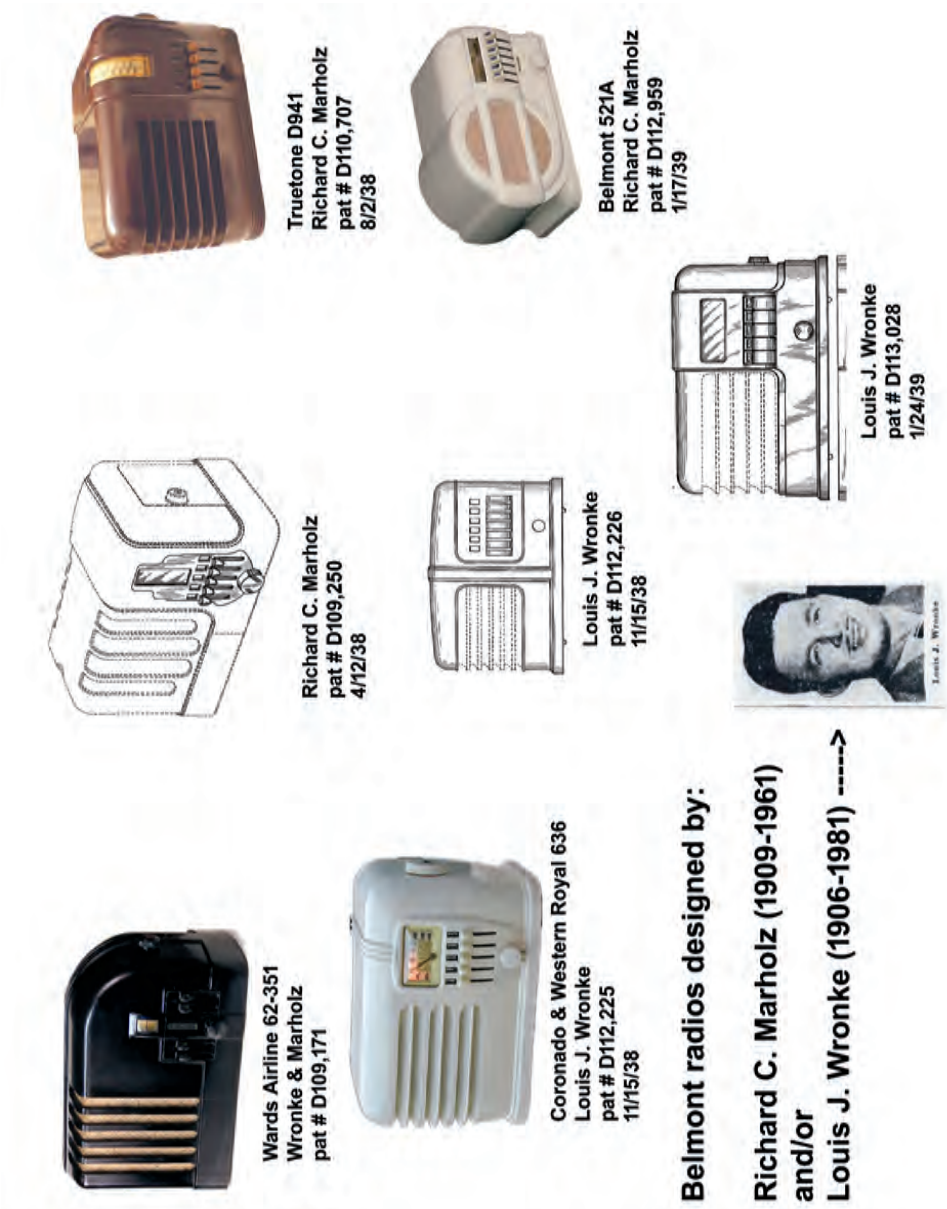


Fig. 34. Some of the designs created by Marholz and Wronke. (Patent numbers: D109,171; D109,250; D110,707; D112,225; D112,226; D112,959; D113,028)

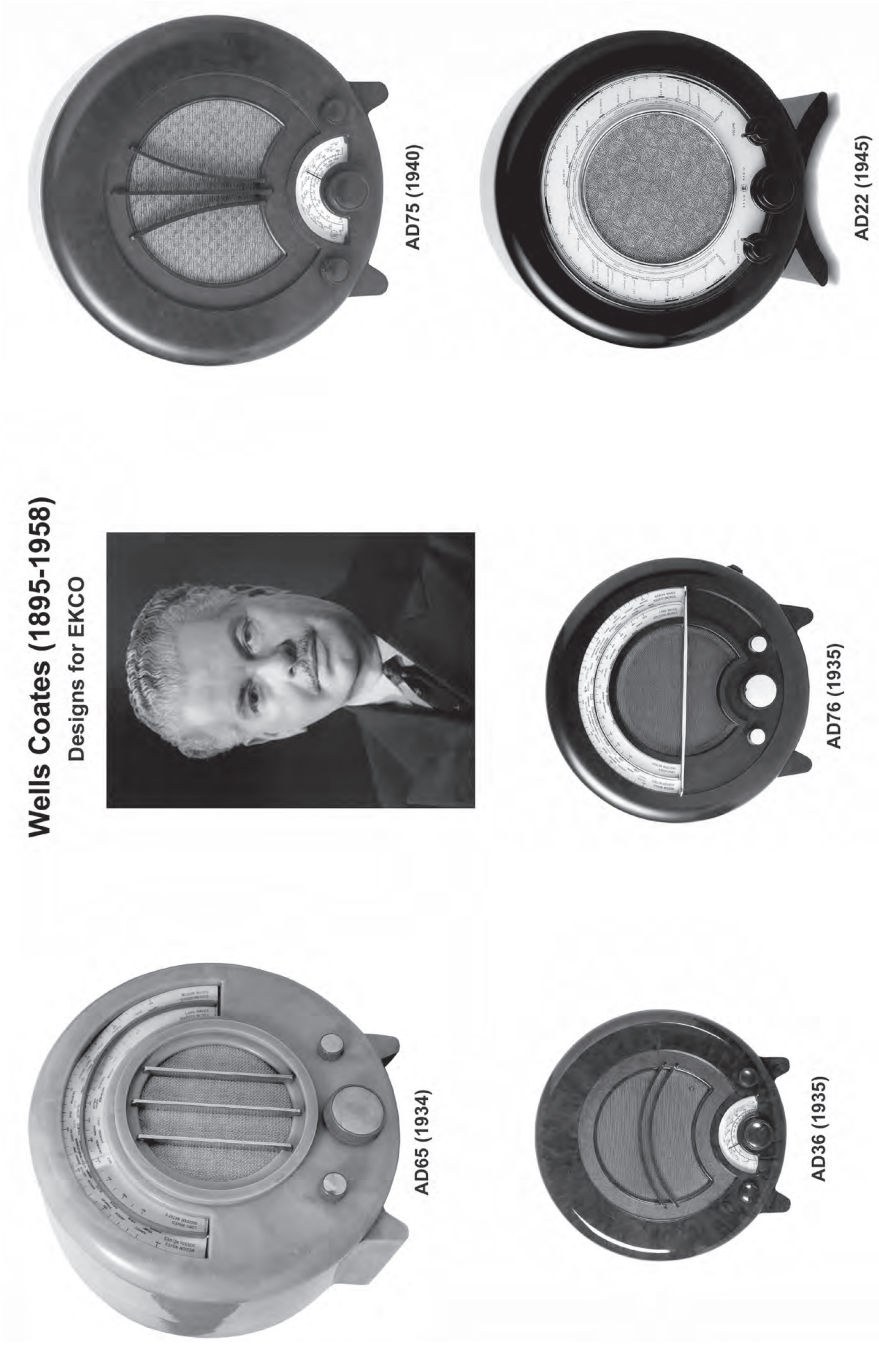


Fig. 35. Wells Coates' round radio designs for the E. K. Cole Company (EKCO) in the United Kingdom. (*Radio Art*, 1991, p. 82; *Bakelite Radio*, 1996, p. 52, 95, 103, 104;)

Endnotes

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3. Alan Douglass, *Radio Manufacturers of the 1920s Vol. 2*, (Vestal Press, 1989) p. 113.
4. Splitdorf ad, *Saturday Evening Post*, Sept. 19, 1925, pp. 178–179.
5. Philco ad, *Saturday Evening Post*, Aug. 18, 1928, pp. 118–119; Bill Denk, "Hand Painted Philcos," *ARCA Gazette*, Vol. 5 No. 3, Fall 1977; Matild Messaros' death notice, *Philadelphia Inquirer*, Mar. 10, 1989.
6. "Draw Your Ideal Radio," *Radio News*, Mar. 1926, p. 1258.
7. "The Ideal Radio Set Results of the $1,000.00 Prize Contest," *Radio News*, July 1926, pp. 8–11.
8. "Westinghouse Radio Idea Contest," *Saturday Evening Post*, Sept. 27, 1930, pp. 68–69.
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    "Unlimited Design Possibilities," January 1934, p. 7.
    "New Freedom of Design for Large or Small Sets," Mar. 1936, p. 35.
    "An International Trend in Radio Styling," May 1936, p. 1.
    "Read the 'Inside Story' of This Radio Styling," Aug. 1936, p. 33.
    "For Quality Styling in Radio Sets," Sept. 1937, p. 45.
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41. op. cit., Gantz, *Design Chronicles*, p. 135.
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About the Author

John Okolowicz has been dabbling with radios most of his life and is currently fascinated by the artistry of old magazine ads as they relate to consumer technology. He is a retired Honeywell engineer after working there for 29 years. For nearly 20 years he also sold reproduction grille cloth. He has previously published articles in *Radio Age* (the Mid-Atlantic Radio Club Newsletter), *Antique Radio Classified*, and the *AWA Review*.

John Okolowicz

Telegraph Wars: Mormons, Native Americans, and the Transcontinental Telegraph

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This article marks the 160th anniversary of the 1861 completion of the transcontinental telegraph in the United States. The basic story is embedded in the mythology of the American West. This article identifies important but often-overlooked parts of the story. The authors explore the strategic wars that were fought over this new, electric communication line. Both the Mormon and Native American experiences reflect positive and even enthusiastic support for building the transcontinental telegraph, but their views diverged as the new technology spurred further settlement, and as it was used to help secure the frontier. These wars, previously thought to be somewhat randomly executed, reflected specific strategic choices applied over a wide-ranging, harsh environment where brutal methods of warfare became the norm. Critically, they reflect a keen awareness by contemporary players about the importance of the transcontinental telegraph and its implications for controlling America's western territories.

Introduction

Historically, major anniversaries of the 1861 transcontinental telegraph received much attention. Today, public awareness of this achievement is often eclipsed or swept into celebrations of the 1869 transcontinental railroad. Historians frequently cite these two accomplishments as key elements that helped facilitate the settlement of America's western frontier by non-native people. We revisit these events focusing on: Mormons and Native Americans, and the contest for control over the new electric communication route.

Terminology

Identification, descriptions, and depictions of Native Americans and Mormons have changed over the years. We adopt the following conventions in this article.

Nineteenth century period texts, press coverage, and documents generally use the word "Indian" to describe any and all native people who occupied the frontier. Over time, these indigenous people, who occupied a vast continent and belonged to dozens of major ethnic groups and hundreds of local tribes and bands, have been described as "friendly" or "hostile" and as Indians, Native Americans, First Nation, Aboriginals, and other terms. Within this article, we identify the native people by their tribe or we utilize the general term "Indian" to be consistent with the source documents and language of the 1860s.

Similarly, the word Mormon has generically referred to a religious or cultural follower of Mormonism. The Mormon may or may not be a member

of the Church of Jesus Christ of Latter-day Saints (a/k/a the LDS Church or Mormon Church), a branch of the LDS Church, or a sect that follows Mormon fundamentalism. Brigham Young is one of several successors who led different groups after the death of the founder, Joseph Smith. We make no distinctions within this article among these groups, despite focusing on Brigham Young.

At the time of construction in 1861, the transcontinental telegraph line traversed areas that were then defined as the state of California and the Territories of Utah, Nebraska, and Kansas. Locations east of these territories had already been incorporated into states. The locations identified in this article reflect the modern state names for convenience of the reader, recognizing that the territories were incorporated at different times into multiple states and that territorial and state boundaries may have changed over time.

Building the Transcontinental Telegraph

Methods for communications across America's western frontier transformed during the years just before the American Civil War. Starting in September 1858, the Butterfield Overland Mail Company carried messages from the Missouri frontier to the Pacific Coast in just 25 days. In April 1860, the Pony Express began delivering messages, newspapers, and mail in only nine days with its legendary courier system of horseback riders. Yet, a new electric system of communications was already heading west.

The Quest[1]

By 1860, the telegraph was well established in the eastern half of the United States, but areas west of the Mississippi River remained largely untouched by this new electric form of communication. Communication west of the Mississippi River by coach, overland mail, and Pony Express followed the established land routes of the Santa Fe Trail, Oregon-California Trail, and Mormon Trail. The famed Pony Express route mirrored much of the Oregon–California Trail west from St. Joseph, Missouri, to South Pass, Wyoming, before heading to San Francisco, California. In 1841, three years prior to Samuel Morse's telegraph demonstration from Baltimore to Washington, DC, news of President Benjamin Harrison's death took nearly four months to reach the small village of Los Angeles. News about the assassination of President Lincoln in 1865 reached the west coast in minutes.[2] The importance of the new east-west electric communication route was heralded as an American achievement, but the project was not always seen as viable or theoretically profitable or worthy of investment beforehand.

In 1858, two events demonstrated that communication times over long distances could be overcome with electricity. Both the Russian Empire and the United Kingdom and its allies built telegraph networks to begin managing their political and military interests regarding the Crimean War. That year also witnessed the completion of the first transatlantic cable, establishing telegraph communication between the United Kingdom and

the United States. The distances traversed by each project were tremendous, involving thousands of miles of land and submarine telegraph lines. Both had varying levels of success, but both demonstrated the viability of the new technology.[3]

In the United States, the telegraph industry evolved quickly after 1850 as many smaller firms gradually shuttered or consolidated their competing interests into large, new, corporate organizations. The Western Union Company became a dominant player by 1856 following the merger of several regional firms into one organization under the leadership of Hiram Sibley and Ezra Cornell.[4]

Early proposals for a transcontinental telegraph by Illinois senator Stephen Douglas in 1848 and 1851 lacked political support. Questions loomed over the possible impact of the proposed telegraph line on the country's politically-heated, sectional divisions of the 1850s. Concerns also focused on the financial feasibility and viability of such an undertaking. Distance (constructing 2,000 miles of new telegraph lines west to California, plus linking up with another 1,000 miles of existing telegraph lines reaching east to New York City), terrain that varied from deserts to mountains, building across hundreds of miles of treeless prairies, potential conflicts with Indians, unknown costs, and uncertain federal subsidies all posed potentially insurmountable challenges. As late as August 1860, even the majority of members in the North American Telegraph Association showed little enthusiasm for the project at their annual meeting in New York.[5]

Western Union's politically powerful first president, Hiram Sibley, decided his company would move forward alone and backed a new proposal from California senator William Gwin. The looming Civil War, California's new statehood, and recognition that maintaining closer connections to the western territories and access to the wealth of California's gold, all helped place a new priority on constructing the telegraph line. On September 20, 1860, Secretary of the Treasury Howell Cobb communicated the government's acceptance of Western Union's bid. [6]

The Pacific Telegraph Act of 1860 authorized the U.S. government to award a construction contract to the low bidder for building a telegraph line from Missouri to California in order "to facilitate communication between the Atlantic and the Pacific states by electric telegraph." The act authorized right of way through Indian occupied land and provided a quarter section every 15 miles for repair stations. Western Union was the sole bidder. The contract specified a completion deadline for construction of July 31, 1862, and provided a subsidy from the government of $40,000 per year for ten years, dictated a maximum rate of $3.00 for a ten word message from Brownville, Nebraska, to San Francisco, prioritized government messages above all others, and provided that the Smithsonian Institution Coast and Geodetic Survey and the U.S. Naval Observatory had free use of the line during the ten year contract.[7]

Western Union formed a separate company for the undertaking, the Pacific

Telegraph Company, which it chartered in Nebraska on January 11, 1861. Western Union's Jeptha Wade orchestrated a consolidation of California's existing telegraph companies into the California State Telegraph Company, which then formed its own Overland Telegraph Company for the undertaking as charted on April 10, 1861. Both the Overland and Pacific telegraph companies were ultimately under the control of Western Union. Wade concluded that the looming Civil War generally gave impetus to the negotiations among the telegraph companies and ultimately hastened the settlement.[8]

Construction[9]

Jeptha Wade oversaw the entire project for Western Union and Sibley. Edward Creighton directed construction for the Pacific Telegraph Company, with Wade as its new president, and built the telegraph west from Brownville, Nebraska, near Omaha. James Gamble supervised construction for the Overland Telegraph Company and built the line east from Carson City, Nevada, the easternmost extent of the existing California telegraph network.[10] The two companies planned for their construction teams to meet in Salt Lake City, Utah (see Fig. 1). Temporary telegraph stations were established at the end of each line and moved daily to maintain communications with each company headquarters. The Pony Express operated between the two moving construction teams, providing an ever-shrinking, physical communication link between them as they moved closer together (see Fig. 2). The telegraph line followed the route first surveyed by Creighton in November and December of 1860 on his cross-country journey

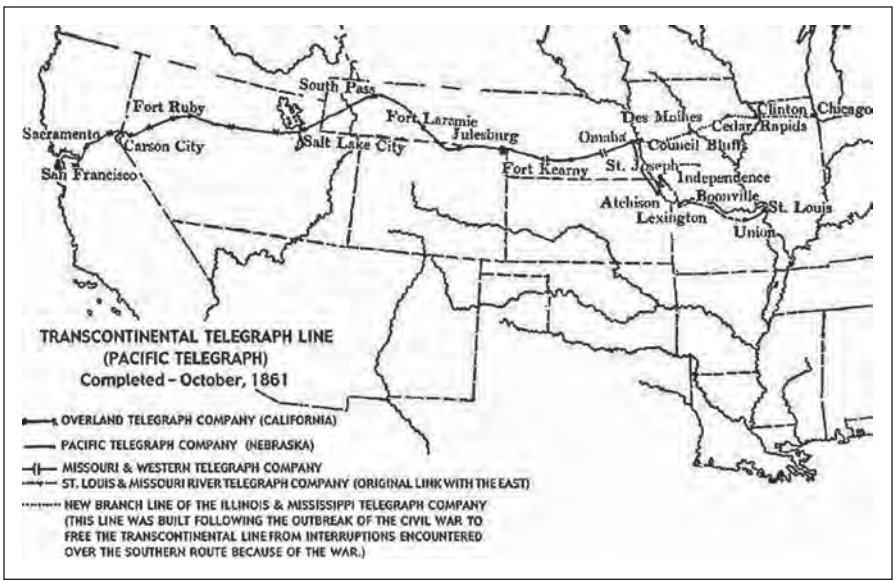


Fig. 1. Map of original transcontinental telegraph route. (Courtesy Thompson, 1947)

Fig. 2. Pony Express rider passing telegraph workers near Chimney Rock on the North Platte River. *(Harper's Weekly,* Nov. 7, 1867)

from Omaha to Sacramento in treacherous, mountainous, winter conditions. His survey identified all available information on a potential route, including timber supply, water, Mormon support, and likely Indian issues.[11]

The challenges seemed nearly insurmountable. Transporting and installing the poles became the most difficult aspect of the undertaking. Poles had to be transported hundreds of miles across the treeless Great Plains. In one stretch between Julesburg, Colorado, and Fort Kearney, Nebraska, poles were largely obtained from Cottonwood Springs, Nebraska, a nine day round-trip.[12] The lack of towns and settlements meant virtually all equipment and materials had to be conveyed from the eastern states or California. Roads were few, waterways were not deep enough for navigation, and unpredictable seasonal flooding posed additional constraints, again implying that construction crews were required to haul nearly everything by wagon trains in a rolling operation as they worked their way across the frontier.[13] Each wagon could carry from 4,200 to 7,800 pounds of cargo, averaging 5,600 pounds each. Telegraph wire was typically the heaviest item.[14]

Gamble's western team erected its first pole on June 20, 1861, at Fort Churchill, Nevada, on the California border and proceeded east. Creighton's eastern team erected its first pole on July 4, 1861, in Omaha and proceeded west. Two additional teams moved outward from Salt Lake City: James Street's team advanced westward, and W. H. Stebbins' team moved eastward toward Fort Kearny. The teams linked and ultimately joined the eastern and western portions of the line in Salt Lake City, completing the first transcontinental telegraph far ahead of schedule on October 24, 1861. The

scale of the undertaking was tremendous: 27,500 poles held 2,000 miles (3,200 km) of single-strand iron wire over a vast terrain that could now electrically communicate in seconds. By extension, the telegraph network spanned 3,000 miles, linking New York City to Los Angeles. Appendix A contains a timeline of the construction.

Moving wagon trains hauled all of the necessary materials, equipment, and labor resources as construction proceeded. In the West, a train of 25 wagons with 50 men, 228 oxen, and 18 mules and horses worked eastward. In the East, 100 wagons, 500 oxen and mules, and 400 men built westward. Each crew was divided into teams: surveyors marked a path, hole-diggers and wagons rolled the poles into location, and wiring parties installed the line onto mounted insulators. Everyone had to match their pacing; e.g. the pole haulers had to keep pace with the pole diggers and line installers, with teams of 5 to 6 men each comprising the pole haulers, ten-man teams as post hole diggers, and two teams of wire parties.[15] Between three and eight miles of line were strung each day, depending on the terrain, and telegraph stations were built or added to existing overland trail stations. The team averaged 10 to 12 miles per day and set a record of installing 16 miles on one day in a race to reach water.[16] The eastern portion of the operable telegraph line moved west each day with construction and had a temporary transmitting station, the "outer station," that maintained communication between the construction crews and Omaha.[17]

When completed, the telegraph office in Salt Lake City could operate with 50 cups of battery acid in a wet cell, sufficient to signal Fort Laramie 500 miles to the east and Carson City 600 miles to the west. These are nearly half the battery requirements of the eastern cities that operated in conditions of higher humidity and had more significant power drain from greater usage.[18] As a result, telegraph stations were generally located every 30 to 50 miles and were used for telegraph offices or to accommodate repair stations. They were as close as 8 to 10 miles apart in the Sierras to permit more frequent repairs in the mountains. Those located away from cities or settlements were often in stockades or blockhouses, but they were also in small log, adobe, stone, or earthen/sod structures in the more remote areas, such as the Mud Springs station in Nebraska Territory northwest of Julesburg. Conditions in many locations were so poor and primitive that General Sherman described them as "hovels."[19] Julesburg itself was considered a large outpost at the time with 40 to 50 station hands, stock tenders, drivers, telegraph operators, etc. The buildings were built of cottonwood logs and sod.[20] The compounds were often square; Deer Creek was about 75 feet × 75 feet.[21] Mud Springs was described as a "dirty hovel" comprised of two sod buildings with pole-and-earth roofs: one housed the telegraph office and quarters for the soldiers, the other served as a combination storehouse and stable, with an adjacent corral.[22] Appendix B includes information about some of the major items used in the construction effort.

Successes and Challenges

Success was immediate. Over 200 private messages passed over the line on the first day of operation.[23] Western Union charged $1.00 per word for messages sent on the transcontinental telegraph in the first week of operation even though the Pacific Telegraph Act of 1860 had specified the rate would be $0.30 per word.[24] Western Union even charged an additional fee for placing the date and place of origin on the telegrams.[25] The projected cost of $267 per mile to be incurred over a two year construction period had been reduced to four months of construction and an actual expense of only $67 per mile.[26] The Pony Express, now obsolete, ceased operations two days after the first transcontinental telegrams were sent.[27]

But the nation's attention focused on the Civil War. Unlike the completion of the Atlantic Cable in 1858, no national parades or other national celebrations followed the announcements of the transcontinental telegraph line's official completion on October 24, 1869. Initial newspaper accounts, although congratulatory and positive, were limited.[28] The *New York Times* proclaimed the success of "this noblest symbol of our modern civilization" two days afterward, finally announcing on October 29 that 200 messages passed over the line the first day it opened, including the text of the first formal message to President Lincoln. *Harpers Weekly* included only a small graphic towards the back of its November issue nearly a month later (see Fig. 3).[29] The *Rocky Mountain News*, the leading regional newspaper, provided a small notice under the heading Local News that the line was open for business.[30] *Scientific American* reported in late November that "The Continental Telegraph"

Fig. 3. The first telegraphic message from California. (*Harper's Weekly*, Nov. 23, 1861)

united the Atlantic and Pacific "by an electric cord 3,500 miles in length…the largest electric circuit in the world…one of the grandest commercial and scientific achievements of the age."[31]

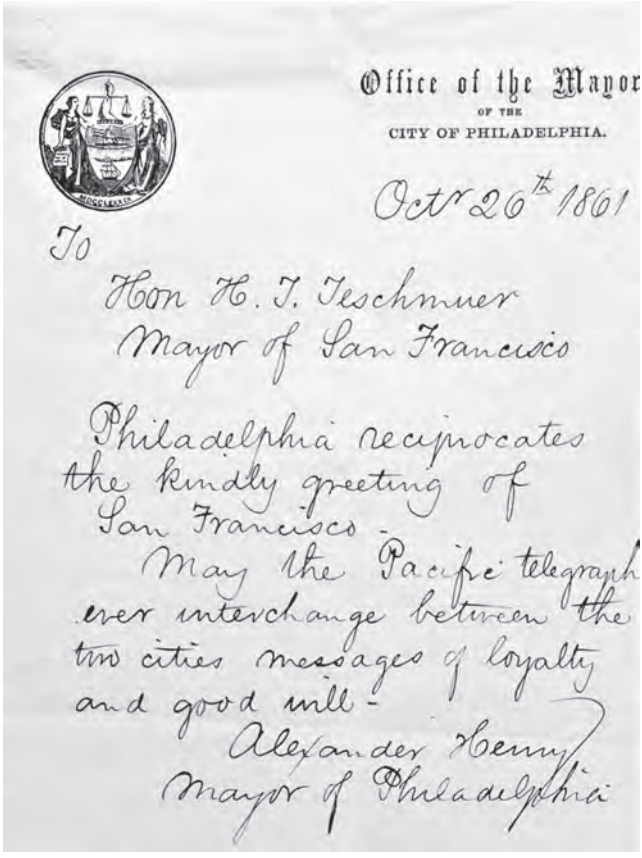
Nevertheless, the transcontinental telegraph was operational thanks to dedicated linemen and operators (see Fig. 4 and Fig. 5). Only seven months earlier, on March 4, 1861, the Pony Express carried news of President Lincoln's inauguration and then news of the Confederacy's bombardment of Fort Sumter. The telegraph could now carry messages from coast to coast (see Fig. 6). Within three years, in October 1864, the newly admitted state of Nevada sent its complete constitution to President Lincoln entirely by telegraph, signaling that a new age of transcontinental communication had become firmly established.[32]

Yet, despite its immediate success, the transcontinental telegraph faced numerous challenges to its continued viability. Weather conditions wore down or destroyed equipment. Lightning and varied soil conditions from bogs to deserts to the Rocky Mountains left the poles unstable in changing weather conditions. Strong winds, heavy rain, and deep snow in some places up to 20 feet deep, damaged both poles and the wire. Bison rubbed against the poles to scratch, knocking them down. Herds of Bison also caused damage or destruction for miles at a time.[33]

The Civil War resulted in a formal rerouting of the Missouri portion of the telegraph line. Within a week of opening the San Francisco telegraph office, Confederate raiders destroyed part of the transcontinental line in Missouri. By October 23, 1861, a decision was reached to reroute the telegraph. By January 3, 1862, in order to avoid further Confederate access to or destruction of Union

Fig. 4. Daguerreotype image of a telegraph operator circa 1860s. (Authors' collection)

Fig. 5. Daguerreotype image of a telegraph lineman circa 1860s. (Authors' collection)


Office of the Mayor
OF THE
CITY OF PHILADELPHIA.

Oct 26th 1861

To
Hon H. F. Teschmuer
Mayor of San Francisco

Philadelphia reciprocates the kindly greeting of San Francisco -
May the Pacific telegraph ever interchange between the two cities messages of loyalty and good will -
Alexander Henry
Mayor of Philadelphia

Fig. 6. Transcontinental telegraph congratulations from the Mayor of Philadelphia to the Mayor of San Francisco, Oct. 26, 1861. (Authors' collection)

telegraph lines in that state, the original route from Omaha south toward St. Joseph onward to St. Louis had been moved north. The transcontinental telegraph line was now routed from Omaha eastward through Council Bluffs, Des Moines, and Cedar Rapids, Iowa, on to Chicago (see Fig. 1).[34]

The Butterfield overland mail was also rerouted north as the Civil War began. The southern route, through the southwestern U.S. territories, was subject to capture by Confederate forces. So, in 1861, the Butterfield's overland mail was reassigned to the Overland Trail under control of the Union. This action secured communication links for the mail and the telegraph to California and ensured access to wealth from the California and Colorado goldfields, which was critical to fund the war effort.[35]

Given the strategic importance of the central east-west corridor to the Pacific Coast at the beginning of the Civil War,

the Indians' nomadic routes across the Great Plains posed a real threat for the Union. Ongoing encroachments by settlers and freighters hauling wagonloads of people and materials across the western emigrant trails through native lands and the ever-changing government policies toward the Indians increased friction. Growing accounts of retaliatory raids and destruction waged by Indians in response to those pressures soon exploded into open warfare (see Fig. 7).

First-hand Experiences

Very few accounts describe the first-hand, personal experiences of those who constructed the transcontinental telegraph. Newspaper stories frequently carried identical or modified versions of the same basic stories. Incidents may have been witnessed, or they were simply retold; and generalizations occurred frequently, especially regarding Mormons and Indians. Some documentary evidence exists in letters, newspaper accounts, telegrams, and government documents.

James Gamble published two articles in *The Californian* in 1881 that memorialize his experiences directing construction of the western portion of the line.[36] Charles Brown, a lawyer and administrator for Edward Creighton on the eastern portion of the line, left a diary that was subsequently published.[37] The reprinted collection of letters by Hervey Johnson, a Union soldier from Ohio who served on the Great Plains from 1863 to 1866, also provides direct accounts.[38] Mormon Church archives and Utah state archives offer insight into Brigham Young and Mormon outlooks, and several authors have explored this subject as noted herein.

Virtually no records exist regarding Indian views, but specialists in Native American and Western American history

Fig. 7. *The Song of the Talking Wire*, 1904 oil on canvas by Henry F. Farny. (Courtesy Taft Museum of Art, Cincinnati, Ohio)

have explored the factual history of Indian responses to the government, the army, and settlers as well as the telegraph. Based on that historical analysis, some conclusions can be drawn about Indian knowledge and strategies as shown by their actions and recorded events.[39]

The remainder of this article draws from these and other sources as noted, focusing on the involvement and contributions of Mormons and Native Americans to the transcontinental telegraph.

Mormons

Mormons made important contributions to the construction and security of the transcontinental telegraph. Distrusted by most of the nation, Mormons held a positive, if wary, political relationship with President Lincoln and reasonable relations with Indians. Mormons offered a ready and local supply of labor and materials for the project. Brigham Young, a prominent Mormon leader, anticipated the benefits of the new telegraph technology and demonstrated his skill in organizing the establishment of Mormon settlements throughout the Utah Territory. He brought those strengths to Western Union and to the United States to help establish and secure the new telegraph line.

Mormons in Utah

The Mormons arrived in Utah Territory in 1847 after fleeing westward from Nebraska, Missouri, Illinois, and the location of their origin in New York. Led by Brigham Young, the Mormons began constructing an isolated society in Utah based on their beliefs and values.

In 1857, the U.S. Army arrived in Utah at the direction of President James Buchanan. The Mormons interpreted their arrival as open aggression. The ensuing Utah War took place from 1857 to 1858. Violence occurred when a local Mormon militia killed a civilian emigrant party that was traveling through the territory, initially placing blame on the Indians for the attack. In 1858, Brigham Young stepped down from his position as governor, replaced by a non-Mormon; however, Young and the Mormon Church still wielded significant political power.[40]

Mormon Relations with the Nation

Prior to and throughout the Civil War, rumors abounded in the Northern and the Southern press that the Mormons planned to secede from the Union and form their own independent nation. By the late 1850s, Mormonism was among the most frequent topics reported in American newspapers. Much of the nation viewed Brigham Young as a despot rather than a religious leader. Questions centered on Mormon trustworthiness, polygamist practices, and the supposed disloyalty of Mormons to the Union. These themes returned after the Civil War as the abolition of polygamy replaced the abolition of slavery as a national moral focus.[41]

Mormon political reactions reflected conflicting themes of a desire for isolation, a search for tolerance of their independent community, and a desire to be trusted and welcomed by the nation, while often resentful over outside intrusions or interference with their way of life.

Lincoln's Relationship with Mormons[42]

Abraham Lincoln entered political life in New Salem, Illinois. His experiences in the Illinois legislature, U.S. House of Representatives, and as president of the United States brought him into contact with Mormons during the period when they settled in Nauvoo, Illinois. He sympathized with Mormon concerns about balancing their needs and those of the general population. Lincoln helped guide the Nauvoo Charter through the Illinois House of Representatives and later assuaged the Mormons in Utah when they struggled with hostile territorial governors appointed by the U.S. government. Lincoln also called for Mormon support during the Mexican American War, including formation and supply of a Mormon Battalion to fight in Mexico.[43]

By 1860, Lincoln and Young recognized in each other a relative trust that eventually supported Mormon interests in constructing and protecting a transcontinental telegraph.[44] By early 1862, Civil War manpower shortages in the North posed security issues for the western frontier. Lincoln requested Young to muster a territorial company of 90 men to patrol and guard the property of the Overland Telegraph and Overland Mail Companies between Fort Bridger and Fort Laramie, Wyoming. The company was raised within three days and provided service that summer under the command of Captain Lot Smith.[45] Yet, calls for an outside Union force prevailed as allegations persisted that robberies and murders along the stage routes were committed by Mormons rather than hostile Indians. The *New York Times* concluded, "The Mormons and Indians are, as things go, doing respectably well at present; and it would not be bad policy to let well enough alone."[46] In the end, the U.S. government sent a company of California Volunteers to establish Camp Douglas in the Salt Lake City foothills in late 1862 to ensure that the Mormons remained loyal and to provide security against Indians.[47]

Mormons reciprocated with overwhelming support of Lincoln, and the Union, throughout his political career.[48] That relationship and sense of goodwill again bore fruit when the transcontinental railroad was built in 1869; with Mormons providing support for railroad construction and for relocating telegraph lines from the original 1861 route over to the new 1869 railroad right of ways.

Mormon Telegraph Contributions

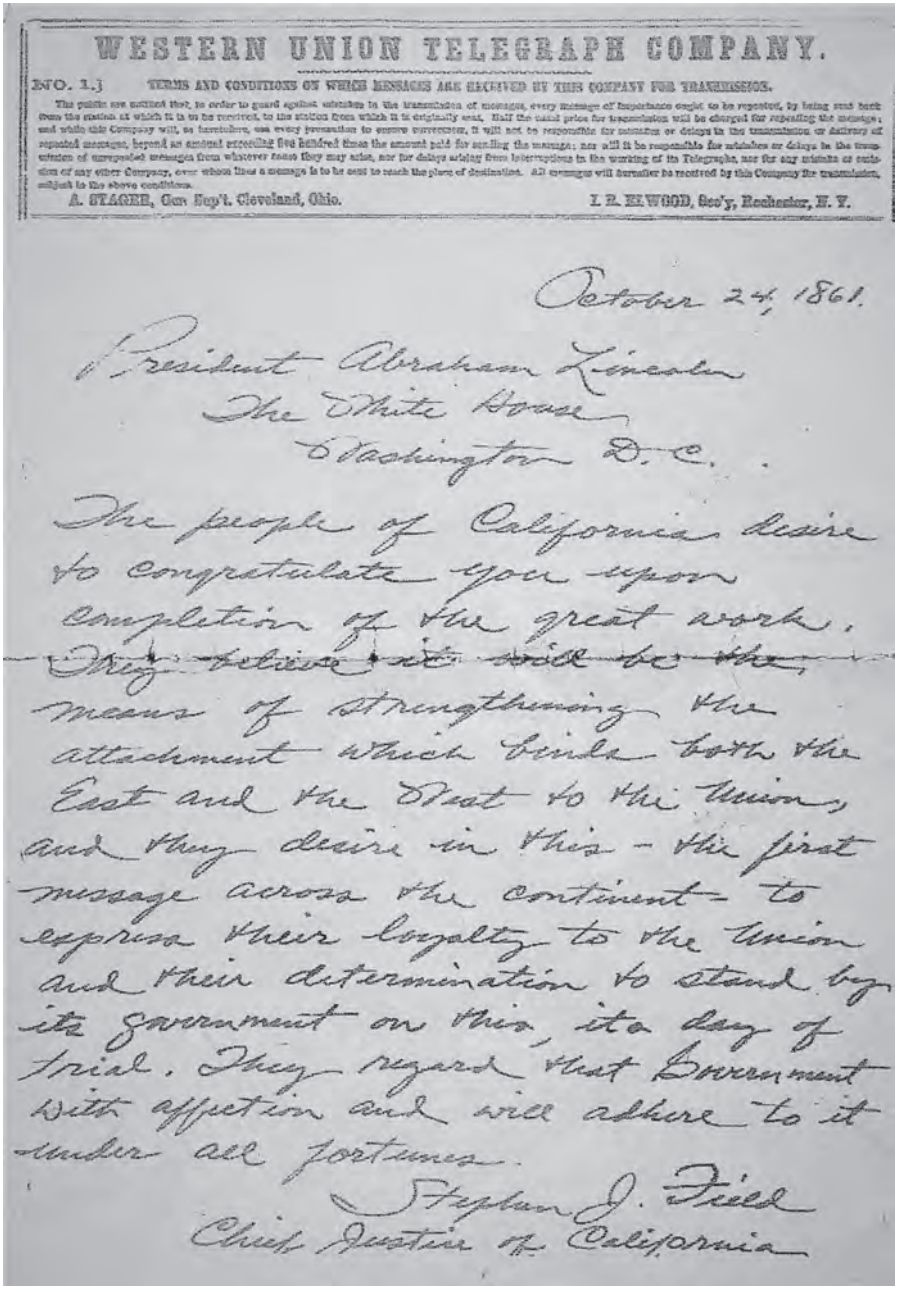
Soon after the Mormons arrived in Utah, calls for a telegraph connecting Utah to the nation arose. In 1853, the Utah territorial legislature petitioned Congress urging construction of an east-west telegraph line through Salt Lake City "to preserve inviolable our glorious Union… by an ELECTRIC stream."[49] Mormon interest remained strong.

As work commenced on the transcontinental telegraph in 1860, Creighton, as agent for Western Union and the Overland Telegraph Company, performed the initial land survey late that year. He worked his way west from Omaha on horseback, completing a 600 mile survey trip to Humboldt Valley and across the Sierra Nevada mountains. He arrived in Salt Lake City by stagecoach

in December 1860. Creighton met with Brigham Young and contracted with Young to oversee and superintend telegraph construction through Utah. Young fully supported the project and agreed to supply 750 miles of telegraph poles, subsistence, and transportation for the eastern line. In return, Creighton recommended that the eastern and western lines should meet in Salt Lake City. Young's son, a lumber dealer, handled the contract. A separate contract with the Mormon firm Little and Decker of Salt Lake City covered another 250 miles of poles destined for the western line.[50] Although the terms of the initial contract soon proved unprofitable, Young honored the original contract. Young received $11,000 in gold as payment, which he turned over to the Mormon Church as tithing. Young also received $10,000 in Overland Telegraph Company stock.[51]

The eastern and western lines met in Salt Lake City at a new telegraph office located on Main Street between First and Second South Streets (see Fig. 8). Given the substantial commitment made by Brigham Young to the enterprise, he was invited to issue the first telegraph message on the eastern portion of the new line. It was sent to Jeptha Wade, president of the Pacific Telegraph Company, upon its completion on October 18, 1861, congratulating the enterprise and assuring everyone of Utah's commitment to the Union. Messages from the Utah territorial governor to President Lincoln were sent on the same day.[52] On October 24, Stephen Field, brother of Cyrus Field and chief justice of the Supreme Court of California, and Horace Carter, president of the Overland Telegraph Company, sent formal congratulations to President Lincoln across the entire length of the line from San Francisco to Washington, DC (see Fig. 9).[53]

Fig. 8. *Completion of the Transcontinental Telegraph*, Oct. 24, 1861, painting by Frank McCarthy. (Courtesy Anaconda Wire and Cable two-page advertisement, *Time Magazine*, May 15, 1953)



WESTERN UNION TELEGRAPH COMPANY.

NO. 1.] TERMS AND CONDITIONS ON WHICH MESSAGES ARE RECEIVED BY THIS COMPANY FOR TRANSMISSION.

The public are notified that, in order to guard against mistakes in the transmission of messages, every message of importance ought to be repeated, by being sent back from the station at which it is to be received, to the station from which it is originally sent. Half the usual price for transmission will be charged for repeating the message; and while this Company will, as heretofore, use every precaution to ensure correctness, it will not be responsible for mistakes or delays in the transmission or delivery of repeated messages, beyond an amount not exceeding five hundred times the amount paid for sending the message; nor will it be responsible for mistakes or delays in the transmission of unrepeated messages from whatever cause they may arise, nor for delays arising from interruptions in the working of its Telegraphs, nor for any mistake or omission of any other Company, over whose lines a message is to be sent to reach the place of destination. All messages will hereafter be received by this Company for transmission, subject to the above conditions.

A. STAGER, Gen. Sup't. Cleveland, Ohio. I. H. HEWOOD, Sec'y, Rochester, N. Y.

October 24, 1861.

President Abraham Lincoln
The White House
Washington D. C.

The people of California desire to congratulate you upon completion of the great work. They believe it will be the means of strengthening the attachment which binds both the East and the West to the Union, and they desire in this - the first message across the continent - to express their loyalty to the Union and their determination to stand by its Government on this its day of trial. They regard that Government with affection and will adhere to it under all fortunes.

Stephen J. Field
Chief Justice of California

Fig. 9. Western Union's Omaha office's original office copy of the first official transcontinental telegraph from the chief justice of the California Supreme Court to President Abraham Lincoln, Oct. 24, 1861. (Authors' collection)

Deseret Telegraph

Brigham Young's enthusiastic support of the transcontinental telegraph yielded labor, food, supplies, and transportation as well as poles for approximately one thousand miles of the total length. Young's awareness of the potential for the technology led him to propose constructing a territorial telegraph network throughout Utah to connect the Mormon settlements in February 1861. He argued the telegraph would link and solidify communication, and it would enhance the cultural bonds among the communities. He also argued the telegraph would expand commerce and settlement growth throughout the territory. The Mormons soon planned for a complete telegraph network, even opening a telegraph school to train operators. The planned north-south line was intended to branch out and run more than a thousand miles. Complications caused by the Civil War resulted in delays, but the concept was never abandoned.[54]

In 1865, Young published a circular within the Mormon communities arguing "we should bring into requisition every [technological] improvement which our age affords."[55] He argued to "stretch a wire through our settlements in this Territory, that information may be communicated to all parts with lightning speed."[56] Plans resembled the initial 1861 concept, anticipating the import of wire and other equipment that could not be manufactured locally in Utah. The 22 foot long tapered poles (8 inches in diameter at the foot and 5 inches at the top) set 70 yards apart would be locally sourced. Tithing obtained from profits of seasonal harvests provided the funds to purchase wire and supplies. Construction finally commenced later that year, and over the next several years the network grew.[57]

Unfortunately, the high prices for telegraph service initially prohibited rapid widespread use of both the Deseret Telegraph and the transcontinental telegraph, but costs did decline over time. For example, in the first week of transcontinental telegraph operation, a 10 word message from Salt Lake City to New York City cost $10.00. Prices were lowered to $7.50 for the next two years, and then declined to $6.75 in 1869. By 1870, the price dropped to $5.50. Ten years later, in 1880, the price was $1.50 for ten words.[58]

Young became the first president of the new Deseret Telegraph Company, a church-owned public utility, and the only telegraph network ever established by a religious community. The Federal government later confiscated the line in the 1880s during the legal battles over Mormon polygamist practices, eventually returning it to the church. The Deseret Telegraph remained under church ownership until it was finally sold to Western Union in February 1900.[59] It had been one of the earliest and largest branch operations connected directly to the transcontinental telegraph.

Mormon commitments to and investments in the transcontinental telegraph satisfied Brigham Young's original goals. The Mormons achieved quick, reliable electronic communication that spurred settlement, facilitated the organization and administration of the Mormon Church, fostered the vitality of the

Mormon social and economic centers, and provided work for hundreds of people.[60]

Today, a monument erected by the state of Utah is located at City Creek Center (63 Main Street) in Salt Lake City, near the original location (73 Main Street) where the transcontinental telegraph lines were connected on October 24, 1861, and which housed links to the Deseret Telegraph (see Fig. 10).

Native Americans

Early Encounters

Prior to the Civil War, operation of the electric telegraph remained a mystery to most people in the United States. Americans primarily lived in rural settings. Few outside of the major cities had any real exposure to electricity. West of the Mississippi River, the frontier remained a rugged and wild environment. Californians of the late 1850s experienced only very limited exposure to telegraphic communication. As late as 1859, the Bee's Grapevine Line, a telegraph line connecting Sacramento to Carson City, was strung between trees.[61]

Gamble recalled that the telegraph was a source of great curiosity and wonder to almost every person on the western portion of the transcontinental telegraph route. Most did not understand the purpose or use of the poles; Mexican locals thought the Yankees were fencing the country with crosses to ward off the devil. Gamble described a demonstration for "native Californians" who were invited to prepare a message for transmission. The crowd rushed out at the first clicks of the telegraph key to see the envelope and message pass along the wire. Since no one saw the envelope pass, they assumed the wire was hollow, or filled with a spirit.[62]

Gamble also described demonstrations given to Shoshone chief Sho-kup.

Fig. 10. Closeup of the monument marking the approximate location (63 South Main Street) where the first transcontinental telegraph line was completed in Salt Lake City. (Courtesy Ravelle Call, *Deseret News*)

The chief and his tribe were curious and interested in the telegraph, and the chief was influential with the Goshutes and Pah-Utes (a/k/a Pahute or Paiute). The group sent messages between two hills and to San Francisco, and the telegraph was explained as a "wire express" that used lightning to talk. Sho-kup met the president of the Overland Telegraph and sent a telegram stating in part, "I like him and like telegraph…All telegraph men treat me well." The Shoshone understood the basic concept of communicating over distance through the wire, and they were intrigued. Exchanges of gifts, food and clothing occurred, and the Overland Telegraph employed many Shoshone to manage and herd oxen, cattle, and other animals during construction.[63]

These measures helped ensure a spirit of trust and respect, and Gamble credited the Shoshone with influencing the other nearby tribes. Gamble issued strict orders that any person in the expedition who caused trouble with the Indians would be dismissed immediately. Another Shoshone chief, Buck Soldier, provided "all the aid possible" and received a double gold locket in gratitude with two daguerreotypes of Gamble and Buck Soldier inside. Gamble recalled that even during the Indian Wars of the 1860s, the telegraph, poles, stations, and operators were never molested or even injured by the Indians along the western portion of the transcontinental line.[64]

Creighton also arranged demonstrations on the eastern line where a Sioux chief and an Arapaho chief sent messages to one another with interpreters. The chiefs were impressed by the telegraph's ability to "tell the truth."[65] But other accounts describe how Indians were invited to demonstrations and given unexpected electric shocks to make them afraid of the wire, including some demonstrations performed by Creighton.[66] Newspaper stories, adventure writers, and others recounted and repeated stories about the ignorant, primitive, or uncivilized Indians. These portrayals described how Indians were shocked, whether intentionally or inadvertently, and stated they were afraid of the wire. Stories about these electric shocks allegedly "circulated with great rapidity among the Indians."[67] Still, friendly relations generally existed between the various tribes and Western Union during construction of the eastern portion of the line and continued for two more years until the outbreak of the Cheyenne War.[68]

Mormons and Indians

Mormon settlements eventually expanded into a region of the Cache Valley in southern Idaho Territory. Travelers on the California Trail and Oregon Trail and the establishment of Salt Lake City in 1847 brought the Shoshone Indians into regular contact with Mormons and others moving west.

Mormon religious beliefs held that Indians were one of the two "tribes" descended from Abraham, and they were the "Lamanites of prophecy" who lived in the ancient Americas.[69] Brigham Young promoted policies that encouraged Mormon settlers to establish friendly relations with the surrounding Indian tribes. He encouraged Mormons to "feed them rather than fight them."[70]

For example, the Shoshone maintained generally friendly relations with Mormons, and Shoshone leaders enjoyed open access to Young and his appointed agents, notwithstanding occasional skirmishes and disagreements over land and encroachment, theft, or retaliation for individual wrongful acts.[71]

Mormon relations with the Indians remained relatively peaceful until 1863, despite lingering distrust over the 1857 Mountain Meadows Massacre when 120 people from an emigrant wagon train headed to California were murdered by Mormon settlers in the Utah Territorial Militia, who acted together with some members of the Southern Paiute Indians during the Utah War.[72] Nevertheless, the central issue remained encroachment onto Indian land. Despite Young's policy, ongoing Shoshone complaints, and support for the Shoshone from the Utah Territorial Superintendent of Indian Affairs, settlers continued to take over native lands and consumed significant food resources, pushing the Shoshone into areas with increasingly poor sources of sustenance.[73] The commissioner of the U. S. Office of Indian Affairs concluded in 1861 that the encroachment of Mormon settlements deprived the Indians of a means to obtain subsistence, leaving the Indians increasingly hostile, destitute, and in need of protection.[74]

Skirmishes and food raids followed as the Shoshone battled starvation and responded by threatening larger scale disruptions of the emigrant wagon trains, overland mail, and the telegraph, as well as a possible general uprising. A band of Shoshone White Knives and Gose Utes were particularly hostile and threatened the Ruby Valley.[75]

In January 1863, the United States Army, led by a detachment of California Volunteers, attacked a Shoshone encampment and killed approximately 300 Shoshone men, women, and children near their lodges in the Bear River Massacre. Tensions peaked, and the Eastern Shoshone signed the Box Elder Treaty in July 1863, and later the Fort Bridger Treaty in 1868. A separate Treaty of Ruby Valley committed the Western Shoshone, also in 1863. The treaties allowed non-Indians safe passage through the region and included provisions allowing for construction and maintenance of telegraph lines, conducting mining activities, and construction of a railroad.[76]

After the Bear River Massacre, the Mormons, already objecting to the army's presence at Camp Douglas and citing claims of harassment by non-Mormons, grew more sympathetic to the Shoshone. Chief Sagwitch and many members of his band eventually became baptized and joined the LDS Church; Sagwitch was later ordained as an elder. Most of the remaining Shoshone eventually built farms and homesteads under LDS Church sponsorship.[77]

Thus, the western portion of the line experienced little direct conflict with Indians. This resulted, in part, from the calmer overall relationship that existed between the Indians and the Mormons. The eastern portion of the line, east of Salt Lake City, underwent a very different experience.

Lincoln's Views

Abraham Lincoln's views and his relationship to Indians reflected his frontier origins and his own ability to separate political issues from personal sympathies. Indians killed his grandfather in 1784. Lincoln volunteered, experienced no combat, and was promoted to a captain during the 1832 Black Hawk War in Illinois and Wisconsin. Politically, he supported candidates, statesmen, and policies that favored various Indian removal programs. Yet, on a personal level, he exhibited sympathy toward Indians. Nevertheless, he helped establish and condoned, although he deeply questioned, the so-called Indian System. In his opinion, the Indians had no option other than assimilating into a "white" world or the "red" man would perish. Under the Indian System, governmental authority over Indians extended through various chains of agencies that often resulted in contradictory policies and left in place significant internal corruption that targeted native peoples. Further, Lincoln knew about and supported harsh policies toward Indian affairs. As president, he did not back away from the executions of dozens of Indians in the Minnesota Indian Wars. Upon learning that Indians possessed firearms often as good or better than the soldiers, Lincoln ordered the arrest and trial by court-martial of anyone who supplied arms to Indians. His support for policies promoting homesteading, mining, and railroading all put the priority on "white" settlement and promoted the national destiny. Ever more generous land grants issued during the Lincoln presidency doomed the Indian's nomadic lifestyle, and Indian removal became Lincoln's accepted course of action.[78]

A transcontinental telegraph posed a challenge for Lincoln. He believed strongly in the possibilities of new technologies, and he relied heavily on the telegraph to conduct his presidency and to manage the Civil War.[79] However, Lincoln was apprehensive about potential Indian interference with a transcontinental telegraph from the start. Lincoln told Sibley in 1860 that the proposed transcontinental telegraph was a "wild scheme" and that "as fast as you build the line the Indians will cut it down."[80] In short, he questioned its viability in view of the unresolved Indian threat to security on the western frontier. Yet, by 1862, he saw the importance of the western communications route more clearly than his generals and stated that maintaining the telegraph and overland mail communications was critical to the Union war effort.[81]

A Telegraph on the Plains

The Plains Indians largely ignored the new transcontinental telegraph line after it opened in 1861. Periodic raids for food, or in retribution for hostile acts by settlers, or to specifically break the line, did occur. One report told about Indians cutting the wire into small sections for use as bridle bits or for ornaments. But, in general, the line was quickly repaired and was not out of service for any significant period, sometimes only for a few hours or a day. The Indians were also deceived

and scapegoated. The Indian Agent for the Upper Platte Agency concluded that unscrupulous "whites and half-breeds" induced some bands of Sioux and Cheyenne into committing depredations upon settlers and emigrants, destroying Indian confidence in the government, and creating general disturbances.[82] Confederate raiders and renegades from the Civil War posed and dressed as Indians, pulling down the wire and burning the poles. Emigrants and settlers also used the poles for firewood and for making ferry cable to cross the Platte River. And Confederate raiding parties in Missouri and Nebraska purposely destroyed portions of the telegraph line, then blamed Indians for the damage.[83] Still, the transcontinental telegraph remained fairly secure.

The state of Indian knowledge about the workings and function of the telegraph remains unknown. Early accounts indicate friendly relations between the tribes and Western Union employees and even exchanges of gifts directly with Hiram Sibley. He realized that seeking Indian cooperation was a better approach than confrontation, and he ordered that wherever possible Indians would be given food and clothing and hired to help string the wires. He further ordered that any employee who antagonized the Indians would be dismissed. Indians are reported to have referred to the telegraph as the "singing wire," or "talking wire," or "humming messenger wire."[84] All of these terms reflect a knowledge that the telegraph was simply a communication device. But things may have changed as the Indians began to appreciate that telegraph signals could summon the army.[85] Later research indicates that the contents of telegrams were generally accessible, and public knowledge was subject to word-of-mouth and gossip, which may have drifted to the Indians from Indian agents and others. It is also likely that Indians observed and interacted with soldiers and civilians, forming their own conclusions about the telegraph and telegram messages. Pawnee Scouts (see below) operating in the Powder River region in 1865 found "scraps of telegrams taken (by warriors) at Julesburg." Some historians have concluded it is very conceivable that Indians gained a rudimentary knowledge of the purpose of the telegraph, which made it a target in war.[86]

Nevertheless, the transcontinental telegraph remained relatively secure from Chicago to Omaha on to Fort Kearney and from Sacramento to Salt Lake City. But, the middle portion, running through the Great Plains east of Denver, became the focus of a strategic war of retribution. In 1864 and 1865, the Cheyenne and its allies engaged in a major strategic war against the U.S. Army and civilians for control of this vital communications route. This stretch included more than 20 main telegraph stations, relay stations every 50 to 75 miles, branch stations, and thousands of poles and insulators running hundreds of miles that linked forts, towns, small settlements, and cities. As one author notes, the transcontinental telegraph line should really be conceived as a semi-permanent route whose access points changed as forts and settlements were built and closed and as the number of

telegraph stations varied over time and as the actual telegraph line was built, relocated, destroyed, and replaced.[87] This viewpoint has merit, especially as the heavily-travelled main east-west corridor through the Platte River region soon erupted into full-scale war. And, the attacks clearly indicated that the Indians specifically targeted the telegraph for destruction.[88]

Sand Creek

By 1861, the army was operating with dangerously low manpower on the western frontier. The commander at Fort Kearny reported that he did not have enough troops to even protect the fort itself from routine looting by civilians and passing emigrants.[89]

Meanwhile, tensions between Indians, freighters, and settlers continued to mount in the northeastern part of the Colorado Territory, leading to an increasing series of reprisals and reciprocal attacks. Treaty violations, depleted buffalo herds, and government failures to pay promised annuities led Sioux and Cheyenne to raid along the Oregon Trail.[90]

Numerous stories began to circulate about attacks by Sioux, Cheyenne, and Arapaho involving up to 1,000 warriors and within 30 miles of Denver. Growing concerns over security along the telegraph line, at telegraph stations and settlements, and along stage routes led Governor Evans to repeatedly request federal troops. Secretary of War Edwin Stanton, preoccupied with Union army troop demands, did not authorize regular troops, but finally authorized local militia and volunteer regiments.[91] Some hope remained, however, when representatives of the Cheyenne and Arapaho met with President Lincoln in Washington in spring 1863. A "Peace Party" tried to negotiate a treaty with all the western tribes. Meager political efforts were followed by a month long set of tours, meetings, and introductions in Washington and New York City, yet no significant policy changes occurred.[92]

Ongoing crop failures, growing scarcity of game, shortages of water, and the government's failure to deliver promised supplies to Indian villages led to even more frustration and increasing Indian raids. Still, as of August 1864, the Indians had never sabotaged or damaged the telegraph poles. That month, things changed. They cut the telegraph line three times between Valley Station and Cottonwood Springs in the first direct attacks by native people on electric communication lines. Raids and attacks continued into the fall as tensions worsened, and the stage lines and overland mail were interrupted.[93]

Army chief of staff General Henry Halleck finally approved actions to quell the uprisings. John Chivington, commander of the Third Colorado Cavalry was eager to fight and kill Cheyenne. In November 1864, he led 800 men on a campaign and attacked and destroyed a village of approximately 200 to 250 Cheyenne and Arapaho, killing and mutilating the victims, two-thirds of whom were women, children, and elders who were residing in a large and peaceful village. The massacre occurred as Chief Black Kettle sheltered under both a large

American flag and a smaller white flag tied beneath it. News of the Sand Creek Massacre was greeted with horror and disdain in the eastern United States and by the regular army. It remained controversial in Colorado, with miners opposed but many in favor of the action as Chivington returned to Denver a hero. Multiple investigations were soon launched by the government, and the army ultimately condemned the attack, but word had already spread quickly among the Indian tribes.[94]

Cheyenne War

No other incident in the long history of the Indian Wars did more to unite the Plains tribes against the United States than the Sand Creek Massacre.[95] The massacre fatally damaged the traditional Cheyenne clan system and the authority of its Council of Chiefs who had maintained a relative peace, and the Dog Soldiers, a militant band of Cheyenne, now rose in power.[96] Arapaho, Cheyenne, and Sioux responded to Sand Creek as allies. Cheyenne Dog Soldiers and Cheyenne chief Roman Nose undertook reprisals across the Great Plains along the South Platte River, slowly moving north toward the Black Hills and Powder River Country. A massive raiding party of over 4,000 Indians formed and moved up and down the South Platte River, and smaller short raids occurred in all directions across Kansas, Nebraska, and Colorado.[97] Red Cloud, Crazy Horse, and other Sioux leaders joined the Cheyenne with 2,000 more warriors.[98]

Indian concepts of warfare differed from European-American styles and objectives of battle. The Indians had a long history of intertribal warfare as tribes fought over access to nomadic hunting routes. The tribes fought for survival as they were gradually pushed west by expanding encroachment from new settlers onto traditional lands. As the Civil War commenced, the Indians learned about the scale of Civil War battles fought in the eastern United States. On the western frontier, violence and brutality were frequently and increasingly reported on both sides of the Indian conflicts. But Indians did not perceive of war as an all-encompassing endeavor, and they did not share the same concept of battle. The Cheyenne noted that the nature of warfare itself had changed, and warfare with the United States was significantly more violent and on a much larger scale than historical skirmishes between tribes. Scalping and mutilation became a common occurrence as the Indians, the settlers, and the army sought retribution; but for the Indians, these acts also possessed a ceremonial or spiritual component and an interpretation that was absent from the acts of non-Indians. Growing frustration with and deteriorating viewpoints about the nature of "enemies" also encouraged more aggressive behaviors in battle. And, historically poor relationships and a desire to wreak vengeance and inflict vendettas, such as between the Pawnee and the Cheyenne and between the Pawnee and the Sioux, produced particularly brutal methods of intertribal warfare.[99] These factors fueled the chaos and the brutality of the Cheyenne War as the Indians fought with strategic goals

of shutting down communications and transportation routes.

For the next two years, the allied Indians launched wide-ranging and large-scale raids and attacks, intentionally destroying telegraph stations and hundreds of miles of telegraph poles, burning settlements and forts, destroying wagon trains, killing or running off the cattle, and shutting down the overland mail and stage routes.[100] Julesburg, in the northeastern corner of Colorado, found itself in the center of the action. It was one of the most important centers of communication in the region as a station location for the transcontinental telegraph, a jumping off point for Colorado goldfields, a junction on the Oregon Trail, and a home station on the Overland Stage.[101]

In January 1865, the Indians selected Julesburg to launch the "systematic destruction of the Denver-Julesburg line and its telegraph offices" (see Fig. 11).[102] Between 1,200 and 1,500 Arapaho, Cheyenne and Sioux attacked and burned Julesburg, destroyed 3,500 sacks of corn, and ran off over 1,000 head of cattle.[103] They cut and twisted the telegraph wires and cut the poles off at the ground, hauling away the poles, burning telegraph stations, and also burning piles of poles. The Indians also cut the poles for hauling their dead and wounded by making "travois." If the Indians could not cut the wires, they attached rope to the wire and rode away on horseback until the wire snapped, dragging the sections miles away to prevent repair. The Indians destroyed the Julesburg, Lodgepole Creek, and Mud Springs stations and every ranch and station within 20 miles of Julesburg.[104] They rendered the telegraph line inoperable for 10 miles toward Denver and 34 miles toward Fort Laramie. Due to the absence of trees on the plains, the nearest replacement poles had to be obtained from Cottonwood Springs, 134 miles away.[105]

Fig. 11. *Burning of Julesburg*, drawn by T. H. Williams. (Courtesy Denver Public Library Digital Collections, Call Number X-9613)

The Indian attacks expanded during the winter and spring, growing in scope with the intention of closing all communications and shutting down the telegraph and overland routes in order to discourage settlement and to protect the buffalo ranges. In one battle, soldiers sought refuge in caves, running temporary telegraph lines to signal for help from Fort Bridger. Hundreds of Indians raided each of the different stations.[106] An account from a different battle indicates a fleeing soldier dropped a saddlebag that was recovered by the Indians. The Indians found military correspondence, orders, plans for troop movements, and faulty counterintelligence, which they then used to direct the destruction of over 80 miles of telegraph lines.[107] The General Superintendent of the Overland Mail reported that at one point, every ranch except one between Julesburg and Omaha, a distance of 370 miles, was temporarily abandoned as settlers fled the escalating attacks. Property damage between Fort Kearney and Denver exceeded $1 million and over 3,000 head of cattle and horses were stolen in just the first few days of simultaneous, coordinated Indian attacks that commenced on August 10.[108] The army responded, in part, by hanging two Oglala Sioux chiefs at Fort Laramie, which had no effect on slowing the raiding and destruction and only exacerbated the animosity of the Indians. The raiding continued unabated.[109]

Military resources remained scarce. The Nebraska territorial governor repeatedly sought help from the federal government, resorting to using local and territorial militias. The army formed the 11th Ohio Cavalry, 7th Iowa Volunteer Cavalry, and other units and sent them to the frontier rather than the Civil War battlefields of the east. Soon, thousands of Union troops were engaged in the fighting as the army tried to maintain a string of posts between Fort Laramie and South Pass like "a string of beads strung on a thread" that stretched 283 miles.[110] In order to protect these stations, the army eventually sent troops to all these places between 1862 and 1864 as well as patrols and temporary camps at other locations. The soldiers were young. For example, in one company of Ohio Cavalry, 92 of the 105 soldiers were under age 23, and 62 were younger than 20 years of age.[111]

Troops not only protected but also rebuilt and repaired the telegraph lines.[112] The cavalry had standing orders to immediately repair any breaks in the telegraph lines.[113] The work was arduous. One account noted that in 40 hours, one infantry unit built 8 miles of telegraph, restrung 21 miles of downed and damaged line, and marched 52 miles.[114] Soldiers and operators struggled to keep up with repairs that were often made at night. Even stagecoach escorts were ordered to "halt the coaches and repair the line as they proceed."[115] The mission above all prioritized keeping the telegraph line connected and functional, so down time could be kept to a minimum and breaks quickly repaired. Soldiers, fearful of being discovered by Indians, muffled their horse's hooves with blankets, padded their hammers, and rode without saddles. Some dug new holes for

poles and other rehung mended wire. In some cases, wire was simply strung on sagebrush or weeds. At times, two wagons were used to haul replacement poles that proceeded in two lines with the men in the center so the wagons could quickly be corralled to protect the men and stock. No talking was permitted, only whispering if necessary. Frequently, military patrols could see the destruction as it was occurring but stayed safe until night concealed their movements to make repairs.[116]

Many soldiers also found they could supplement their government pay when off-duty by learning Morse code and providing service as telegraph operators or repairmen for Western Union, the Overland Telegraph, and Pacific Telegraph companies, as they provided even more help to keep the stations running.[117]

In the opening attack on Julesburg, over 300 poles were cut close to the ground and the wires were left twisted and tangled.[118] Standing orders stated all military personnel "promptly repair the wire whenever required without waiting for orders to do so."[119] But repair patrols were frequently attacked and butchered, leading some of the troops to plead for duty away from the telegraph lines.[120] One commander noted, "The Indians had evidently good teachers and did their work well. They have got over their superstitious idea that it is bad medicine to touch the Telegraph."[121] Consequently, telegraph repairs were frequent and often only temporary, with portions of the line simply propped up on sticks. By summer 1865, transcontinental telegrams were being delayed by up to a month.[122] West of Fort Laramie, the Indians "seemed to be everywhere" as they repeatedly attacked the army's outposts and effectively controlled the North Platte River Road.[123] An army major described the Indians as "among, if not the best horsemen in the world."[124]

A Raging Inferno

In the late 1850s and early 1860s, the army acted as both mediator and enforcer to keep order between settlers and Indians. Yet, the boundaries of various territorial commands changed with "amazing frequency" as state militias and volunteers supplemented regular army activities. Periodically, the entire system reorganized. The Civil War further upset the normal command structure. Between April 1861 and August 1866, army divisions and departments were rearranged 90 times. At various periods, the western frontier along the route of the transcontinental telegraph included the Department of Utah, Department of the Platte, Department of California, and the Department of the West. These frequent changes strained the command structure, lines of authority, and the consistency of army reactions to the Indian situation.[125]

Manpower shortages continued to be a problem. Despite the appearance of large troop counts, the distances involved were immense. General Dodge reported in August 1865, that Connor's command at Fort Laramie had 7,700 cavalry and 2,100 infantry to cover 2,650 miles of telegraph and overland roads.[126]

The army launched the Powder River Expedition of 1865 (a/k/a the Powder

River War or Powder River Invasion), a large and wide-ranging operation against the Lakota Sioux, Cheyenne, and Arapaho as they moved north into Montana Territory and Dakota Territory. Yet, despite the effort, the army failed to mount an offensive or to decisively defeat the Indians, and failed to secure peace in the region. The expedition found itself doomed by weather and terrain.[127]

Still, the army's efforts succeeded in driving the Indians at least 100 miles away from the telegraph and stage routes, and the army succeeded in rebuilding 600 miles of telegraph lines between Omaha and Denver.[128] One trooper reported working in temperatures from 5 to 10 degrees below zero that winter: "We ran twelve miles of wire and set eight miles of poles, had two severe fights, and marched 55 miles in 52 hours. Operators furnished valuable service. -- E. B. Murphy, Capt. 7th Iowa Cavalry."[129]

By spring, the western prairies of the 1860s were filled with native bluestem, a highly flammable, tall prairie grass that thrived in the wide-open grassland environment. Tolerant of draught conditions and resilient in flooding and fires, the grass provided forage for buffalo, horses, and cattle and drew the nomadic Indian tribes along their traditional hunting routes, bringing them back south and offering them renewed opportunities for conducting raids and wielding destruction.[130]

In 1865, General Robert Mitchell was commander of the military District of Nebraska. Responses to the destruction of Julesburg and ongoing destruction of the telegraph lines proved unsuccessful as several army expeditions failed to trigger an overall decisive battle. Sherman's March to the Sea in the Civil War Savannah Campaign during November and December 1864 was recent news, and reflected a new, total war, scorched earth approach to subduing a resistant enemy. Mitchell conceived a plan to destroy the territory south of the transcontinental telegraph line and North Platte River between Denver and Fort Kearny, rendering the land uninhabitable to force the tribes out of the area. Mitchell ordered every ranch and military outpost to set fire to the prairie on January 27, ahead of the spring growth period. Different methods were used to start the fire. Horses pulling flaming bales of hay wrapped in chains helped spread the fire. Set to the south and west, a northwesterly wind kept the fire south of the transcontinental telegraph line. For the next three days, a massive conflagration spread over 300 miles. The raging inferno swept the country clean, and laid waste to 25.6 million acres (40,000 square miles) of the ecosystem that was central to the Indian way of life. Firsthand accounts state the fires "rolled as a vast confluent of flame." The scale of destruction was equivalent to burning the entire state of Ohio and remains today as the largest fire by far ever intentionally lit on the North American continent (see Fig. 12).[131]

Setting prairie fires to drive game was a familiar hunting strategy used by the Plains Indians.[132] Indeed, the Indians even threatened to burn out the grass forage along the Overland Trail to hinder the emigrant wagon trains and the overland mail that depended on it to

Fig. 12. Map of the January 27, 1865 prairie fire. (Courtesy "Map of the United States And Territories, Together with Canada &c," S. A. Mitchell, Philadelphia, PA, 1867, Authors' collection).

feed their horses and stock.[133] In October 1864, General Curtis and Colonel Livingston seized on this strategy when they set fire to the prairie south of the Platte Valley, burning 200 miles between Julesburg and Fort Kearney as far south as the Republican River. Their attempts to quell the violence were not successful, and Indian raids continued in November and December 1864 until severe winter weather discouraged further attacks.[134] But the scale of the January 1865 fire was unprecedented. The Indians reportedly survived the fire itself, but the destruction succeeded in driving away the buffalo and other game, meeting the army's goal of making the region temporarily uninhabitable.[135] The Indians responded with a second attack on Julesburg in February 1865, burning the outpost and destroying the telegraph lines for 50 miles.[136]

Aftermath

The warfare continued into 1865. At one point in April 1865, four cavalrymen were left to serve as line repair crews at each telegraph station (Three Crossings, St. Mary's, and South Pass) with fourteen-man infantry detachments assigned to the larger combined mail-stage-telegraph stations (La Bonte Creek-Camp Marshall, Horseshoe Station, Deer Creek, and Platte Bridge).[137] The Indians responded by again interrupting communications, tearing down sixteen miles of telegraph line between Horseshoe Station and La Bonte Creek, then attacking and burning St. Mary's Station, and stampeding the herd at Sweetwater Crossing in May.[138]

The strategic attacks on the transcontinental telegraph during the Cheyenne War of 1864 and 1865 have been characterized as "the first sustained, long term, ongoing attack by indigenous peoples against the means of electric communication wielded by an occupying power on the North American frontier and perhaps anywhere in the world."[139]

Indian strategy produced a sustained series of attacks over hundreds of miles. They focused on producing a "denial of service" that destroyed the electrical communications, which were important to the army and settlers. The repeated destruction of hundreds of miles of telegraph in the Cheyenne War far exceeded any efforts made by the Confederate army to disrupt electrical communications in the Civil War, or even British tactics used in the Crimean War regarding the Russian Imperial Telegraph.[140] The Indian attacks in the Cheyenne War "marked the beginning of a period during which the Indians systematically cut wires and burned telegraph poles as part of an ongoing guerilla action against the government of the United States and its agents."[141]

Between August 1862 and January 1867, the army engaged in forty battles and skirmishes and mounted four major expeditions against the Indians. Geographically, 29 battles and three expeditions took place within the borders defined by the current state of Wyoming.[142] Even so, the army did not successfully respond to the Indians' rapid strike-and-retreat strategies, and some personal accounts heavily criticized corrupt and incompetent officers.[143] Other accounts argue that political vacillation, inconsistently applied and changing policies, and the use of poor quality volunteers and "Galvanized Yankees" (former Confederate prisoners of war) rather than regular army troops all contributed to an environment deemed by both Indians and army leadership as unreliable for everyone.[144] Some historians have concluded that the army did not systematically collect, share, or debate information about how to fight the Indians, and it did not develop effective or consistent doctrines or policies to deal with the separate tribes.[145] Others argue that the frontier simply took second priority to winning the Civil War, and General Grant simply could not spare the military resources. Consequently, President Lincoln, General Grant, and army chief of staff General Halleck repeatedly reorganized the western armies—vaguely hoping for a solution while they simultaneously reposted officers out into the western region after they had not performed on Civil War battlefields. Western generals and their staffs showed no ability to effectively control their troops. Further, the government underestimated the mobility and elusiveness of the Indians who had better horses that could outdistance army pursuers and who could subsist on the open prairie while the Indians avoided getting caught in a large battle.[146] One account described an attack on the Platte Bridge Station where the army responded by sending soldiers loaded in mule-drawn wagons that were no match for the Indians on their ponies.[147] Nevertheless, the army did keep the telegraph lines operating, built and enlarged stations, and engaged in ongoing skirmishes with Indians. Thus, the army accomplished an important part of its mission: to maintain open communications between the western United States and the eastern portion of the Union.[148]

The Cheyenne War never ended in a decisive battle; instead, it slowly extinguished. The Indians migrated north into Powder River Country, west of the Black Hills, as they were pushed by relentless settlement that could not be contained. Finally, in October 1867, the Arapaho and Cheyenne signed the Medicine Lodge Treaties. The three part treaties concluded negotiations with the Kiowa and Comanche; the Plains Apache, Kiowa and Comanche; and the Arapaho and Cheyenne. The terms dictated that the Arapaho and Cheyenne would relocate to Indian Territory (Oklahoma). Over time, both the United States and the tribes failed to honor a number of articles in the treaties.[149] Many younger members of the tribes decided to keep fighting. In 1869, the army finally defeated Cheyenne Dog Soldiers led by Tall Bull at the Battle of Summit Springs, marking the end of Indian resistance in Colorado.[150]

Earlier, in November 1868, the Sioux, Arapaho, Cheyenne, and four other tribes concluded Red Cloud's War for control of the Powder River region, closing the Bozeman Trail and numerous forts under terms of the Fort Laramie Treaty.[151]

The Telegraph and the Railroad

Native Americans and the Civil War

At the end of the Civil War, it took several months for the remaining Confederate armies to surrender. The Confederate Brigadier General Stand Waite, a Cherokee Indian chief, surrendered the final Confederate forces at Fort Towson in Indian Territory (Oklahoma) on June 23, 1865, more than two months after General Grant accepted General Lee's surrender at Appomattox Courthouse on April 9. President Andrew Johnson declared the rebellion officially ended on August 20. Given the Indian warfare regarding the transcontinental telegraph, it seems ironic that the final military unit of the Confederacy itself was led by a Cherokee chief.[152] During the course of the war, 28,693 Native Americans served, primarily in the Confederate military.[153] Their participation in the military has continued to this day with nearly 19 percent of Native Americans serving in the armed forces, compared to an average of 14 percent of all other American ethnicities.[154] That participation included protecting the transcontinental telegraph.

Pawnee Scouts

Indian scouts were commissioned by the U.S. government to protect the telegraph and later the railroad. They enlisted for various reasons. Preservation of cultural identity and traditions in warfare, opportunities to respond to historic rivalries among the tribes, or desires to obtain more favorable treatment and protection from the U.S. government may be just a few of the motivations. As war broke out on the Great Plains, the government needed a native force that understood the terrain, knew the locations and nomadic routes of other tribes, and grasped the techniques of warfare and the military strategies employed by enemy tribes. The government also needed to show that Indians could be assimilated and "civilized" into supporting the United States.[155]

In 1864, the army authorized formation of two companies of United States Scouts, primarily comprised of Pawnee Indians. The Pawnee were long time competitors of the Arapaho, Comanche, Kiowa, Crow, Sioux, Shoshoni, and the Ute. For them, warfare against these other tribes as U.S. Scouts was simply a continuation of ongoing tribal conflicts. Pawnee Scouts served during the peak period of the Cheyenne Wars and in the Powder River Campaign of 1865. They were specifically recruited to protect the telegraph lines, stations, and emigrant trails. They engaged in numerous actions, capturing hundreds of Indian horses, tracking and locating Indian villages and war parties, and saving soldiers in battle or those who were lost on the northern plains. They also engaged in repairing of the telegraph lines and aided civilian officials in law enforcement. The units were deactivated in 1866 after the Cheyenne War.[156]

Although mustered into the regular army, the Pawnee Scouts were not a regular force. They maintained their cultural norms, frequently discarded most of their uniforms, and maintained their customs of warfare including use of weapons, rituals, and methods of attack. Nevertheless, they earned a reputation as a formidable fighting force and made important contributions to securing the communications routes across the Great Plains.[157]

The U.S. Scouts were reactivated from 1867 to 1870 with authorization to organize a battalion of up to 1,000 Pawnee Scouts. Two companies served in 1868, four in 1869 and two in 1870. Approximately 800 Pawnee Scouts played a major role patrolling the Union Pacific Railroad and guarding the railroad and telegraph workers and the livestock from the Sioux and Cheyenne, who were sabotaging both the railroad and the telegraph along the eastern portion of the transcontinental railroad. The Pawnee Scouts became a common sight, frequently bivouacking near or with construction crews (see Fig. 13 and Fig. 14).[158]

In August 1867, Cheyenne attacked the Plum Creek Station, destroyed the telegraph, detached one of the rails, and used the telegraph wire to bind detached rail ties into a barrier in order to sabotage the train, which derailed and was looted and burned. The army responded to the Plum Creek Massacre by sending in Pawnee Scouts who successfully engaged the Cheyenne in the Battle of Plum Creek. The Pawnee Scouts effectively ended Cheyenne attacks against the railroad

Fig. 13. Cheyenne tearing up tracks of the Union Pacific Railroad. (Courtesy Utah State Historical Society via Mountain West Digital Library, Building the First Transcontinental Railroad Exhibition)

following the Battle of Plum Creek, and in 1869, after numerous actions, the Pawnees effectively ended the military power of the Cheyenne Dog Soldiers, although some argue that the timing of the Cheyenne religious cycle played a large role. Pawnee Scouts later served in the Red River War in 1874 and in the second Powder River campaign in 1876–1877. This campaign was the last time they operated together in an all-Indian unit, although a few continued to serve individually. Several later joined Buffalo Bill's Wild West Show. Most readjusted to life in Indian Territory (Oklahoma).[159]

O. G. Hammond, superintendent of the Union Pacific Railroad, concluded in 1870 that the government's hiring of the Pawnee Scouts proved a cost-effective means for securing and controlling 400 miles of railroad (see Fig. 15 and Fig. 16).[160]

Fig. 14. Photograph of four Pawnee Scouts and an interpreter. (Courtesy Nebraska State Historical Society, Image RG2065. PH:3 5)

Fig. 15. Stereoview of Pawnee warriors at the 100th meridian excursion in October 1866. The Union Pacific railcar on the left transported President Lincoln's body to Springfield, Illinois for burial the prior year. (Courtesy Union Pacific Historical Collection, Stereocard No. 204)

Fig. 16. United States Scouts Indian Wars military hat badges. (Authors' collection)

The End of the Indian Wars

The Indian Wars spanned a period of fifty years in the second half of the 19th century and early 20th century. Regionalized conflicts involved disputed land, transgressions committed by settlers and Indians, atrocities and retributions, and treaty violations. A shifting network of military forts came and went, and telegraph networks both permanent and temporary were constructed by commercial enterprises and the military.[161] As late as 1915 and again in 1923, the Ute and Paiute Indians even fought against Mormons and Navajo policemen over land rights and livestock.[162] News of these wars traversed the nation via the transcontinental telegraph. From Little Big Horn in 1876 to Wounded Knee in 1890, the nation now learned about these events through press accounts sent by wire.

In the end, General Sherman and General Sheridan, both strong proponents of the transcontinental railroad, were the key architects of overall army strategies in the Plains Indian Wars after 1865. Sherman even created the new Department of the Platte as part of an overall reorganization focused on professionalizing the army and solving the "Indian Problem." The sole purpose of the Department of the Platte was to protect the railroad and telegraph construction crews.[163]

Sherman and Sheridan ultimately decided to deprive the Indians of buffalo and other sources of sustenance as the critical approach to winning an elusive and wide-ranging series of guerilla style wars that could not deliver a decisive engagement. Both the army and civilians embarked on slaughtering the buffalo, transporting many of their horns, heads, and hides east on the railroads, or simply abandoning their carcasses on the plains. A calculated policy of "destroying the buffalo in order to conquer the Plains Indians proved more effective than any other weapon." As Sitting Bull later said, "A cold wind blew across the prairie when the last buffalo fell."[164]

The Transcontinental Railroad Reroutes the Telegraph Line

In the years after 1861, the transcontinental telegraph network expanded. The telegraph's importance to the Union in waging the Civil War proved critical.[165] The original 1861 telegraph route, which followed portions of the Pony Express route, was relocated multiple times as the transcontinental railroad came into existence. Creighton fought to have Omaha designated as the eastern terminus of the

Union Pacific Railroad (UPRR), and he later contracted with Union Pacific to install their telegraph lines. Completed May 10, 1869, a ceremonial Golden Spike joined the eastern and western portions of the transcontinental railroad at Promontory, Utah. The telegraph, operated from a table at trackside during the ceremony in the country's first nationwide hookup, simultaneously signaled the three last blows of the hammer, "Dot, Dot, Dot, Done."[166] The telegraph signal was sent with UPRR, Central Pacific Railroad (CPRR) and Western Union telegraphers operating the UPRR and CPRR sides of the line and Western Union linking them at Promontory. Western Union completed its rerouting of the line north of Salt Lake via Promontory on August 30, 1869 (see Fig. 17).[167]

The Pacific Railroad Act of 1862 established the basis for building the transcontinental railroad on public and on Indian land. Section 2 stated: "The United States shall extinguish as rapidly as may be the Indian titles to all lands falling under the operation of this act and required for the said right of way and

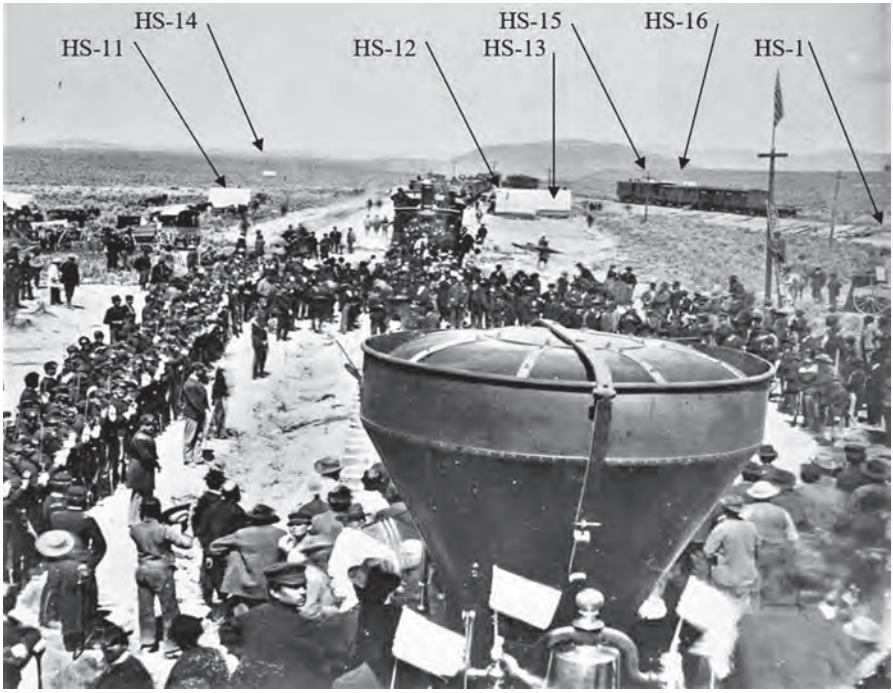


Fig. 17. A labeled view at Promontory Summit post ceremony. Tents HS-12 and HS-13 housed UPRR and Western Union telegraph offices, and the American flag is tied to the telegraph pole under the label HS-1. The flag marked the centerline where the Golden Spike was installed; telegraphers are standing on the ladder and at the base of that telegraph pole. Tent HS-1 housed the CPRR telegraph office that also included Western Union's personnel. Western Union connected the UPRR and CPRR telegraph lines and also utilized tents not visible in this photograph, HS-2 and HS-4. (Courtesy Spude, 2005, p. 60)

grants hereinafter made." The Post Roads Act of July 24, 1866 (a/k/a Telegraph Act of 1866) provided open access to public lands "to construct, maintain, and operate lines of telegraph through and over any portion of the public domain of the United States." This permitted the construction of telegraph lines along post roads and along railroad right of ways. The courts further interpreted the Act as conferring the right of consent upon the railroad companies who owned the right of way, and not the state legislatures. This led to increased use of exclusive contracts between railroads and telegraph companies, which greatly increased the power of the railroads over the telegraph companies, but also benefited Western Union in maintaining its monopoly.[168]

Beginning as early as 1862 and in 1868, portions of the original transcontinental telegraph route were being relocated along the designated new transcontinental railroad route.[169] This provided Western Union with access to more rapid transportation of equipment and telegraph laborers along the circuit, thereby facilitating quicker service times for repair and maintenance. The greater ease of transportation enabled increased security over and continuing expansion of the commercial telegraph network. The railroads provided a much more effective means of transportation than wagons and oxen to haul poles and other telegraph equipment hundreds of miles. So it was logical to move the original telegraph lines closer to the railway. Over time, the railroads themselves gradually established their own telegraph systems for dedicated use in railroad operations.[170]

The impetus for these relocations came from General Sherman, who considered the original telegraph and overland mail route to be duplicative of the new transcontinental railroad route. He viewed the railroad as providing the best opportunity to consolidate transcontinental transportation and communication. In his opinion, the railroad provided the only logical way to conduct future military operations against the Indians, and the telegraph should follow the railroad.[171]

As the telegraph system rerouted and then expanded, the old single line proved insufficient, and multiple telegraph lines were needed on each pole. Multi-line wire systems soon became the norm. Multiple crossbars, or crossarms, on the poles separated railroad telegraph lines from Western Union telegraph lines. Thus, over the years, the original telegraph line was largely dismantled, and its materials were reused, stolen, or lost.[172]

Legacies

Western Union absorbed the Pacific Telegraph Company in 1864 and the Overland Telegraph in 1866. That year, Wade became the third president of Western Union, a position he held for one year due to ill health. Western Union purchased control of the California State Telegraph in 1867. (See Appendix A) Western Union now had direct control rather than indirect oversight of the transcontinental telegraph line and its branch network lines. Competing transcontinental lines built by the United States Telegraph Company (incorporated in 1864) and by the Atlantic & Pacific

Telegraph Company (chartered in 1854) all eventually succumbed to competition and were also absorbed into Western Union. Gamble eventually became General Superintendent of the Pacific Division of Western Union after Western Union's merger with the United States Pacific Telegraph Company and the expansion of telegraph services along the west coast.[173]

In 1869, upon the driving of the Golden Spike, parades were held in Omaha, San Francisco, Chicago, and New York. In Omaha, one parade float had a wagon and poles strung with wire and a telegraph operator sitting at a table dispatching the "lightning." A side banner read "The Pacific Telegraph—projected and constructed by a citizen of Omaha" that referred to Edward Creighton. He was at Promontory Point, and chairman of the Golden Spike ceremonies. Gamble was also present at Promontory, working in the CPRR telegraph tent and temporary office on behalf of Western Union, which did not yet have a telegraph line at Promontory and had just opened a branch off its transcontinental line from Ogden to Corinne.[174]

Today, interest in the transcontinental telegraph is largely obscured by the romantic tales of the Pony Express and tales of building the transcontinental railroad in 1869. However, academics and collectors continue to probe this history, offering new perspectives about the technical and commercial innovations, the military significance, and its cultural impact. Upon its silver anniversary, the Federal Communications Commission summarized the impact of the telegraph: "Invention of the steamboat and locomotive reduced greatly the time element in communication. But it remained for the telegraph to strengthen our national life and unity... [It was the] telegraph [that] provided speedy communication at the time the West was being opened."[175]

Myths and Legends

The mythology surrounding the history of America's western frontier has evolved, and the perspectives of the American public have changed over time. The history of the Indian Wars is complex and multifaceted with many diverse actors and motives, all competing with one another. Questions about whether the Indians or the settlers were savage or noble, heroes or villains, perpetrators or victims, and whether the army and the government served or protected the interests of one party or another in a diffuse conflict that largely centered upon issues of geographic displacement over nearly three centuries of struggle all lie outside the scope of this article.[176]

The mythology surrounding construction of the transcontinental telegraph has been somewhat anchored by Zane Grey's 1939 novel *Western Union* and a 1941 20th Century Fox movie of the same name that was based on the novel. The movie included a number of recreations of historical settings and scenes based on Creighton's experiences along the eastern portion of the transcontinental line. It features the building of the transcontinental telegraph, wagon trains, treks across the Great Plains and mountains, installation of telegraph offices and the telegraph lines,

and stylized encounters with Indians. The movie was intended not only for cinema audiences but also as an educational vehicle to be discussed in schools. 20th Century Fox produced educational posters about the transcontinental telegraph, emphasized reading the novel, and celebrated the accomplishment, while promoting an appreciation of history as part of its worldwide marketing campaign (see Fig. 18). This was a much different approach than the 1933 Warner Brothers movie starring John Wayne in *The Telegraph Trail*, which uses the building of a telegraph line to feature a more typical western movie plot with stereotyped Indians, a scoundrel, a hero, and a heroine. In the 1951 RKO movie *Overland Telegraph*, Tim Holt plays a cowboy who tries to prevent the sabotage of a transcontinental telegraph station before the nearby army post is abandoned.

Several books also helped educate the public while further promoting many of the myths surrounding the transcontinental telegraph, such as the novel *Wires West* by L. V. Jacks (1957) and the historical account *Wires West* by Phil Ault (1974). The adventures of telegraphers also featured in western historical magazines produced for the general public, such as *Golden West* and *The West*.[177]

In 1939, Paramount Pictures released *Union Pacific*, directed by Cecil B. DeMille, based on the 1936 novel *Trouble Shooter* by Ernest Haycox. The movie focused on the transcontinental railroad as a technological advance that helped unify the nation. Several scenes depict telegraph operations, Indian battles, and other western movie genre plot lines.

Fig. 18. Educational poster from the 1941 *Western Union* movie, poster 3 from a set of 11, showing pole installation, pole climbing strap-on hook, come-a-long line pulling equipment, telegraph operators, and an Indian attack. (Authors' collection)

Remnants and Markers

The roughly ten years between the emergence of the transcontinental telegraph and the completion of the transcontinental railroad brought tremendous growth to the states and territories along the route. In 1860, those states and territories had a combined population of 554,301 that doubled to 1,011,971 by 1870. The 132 miles of telegraph and 32 miles of railway in 1860 jumped to 13,000 miles of telegraph line and 4,192 miles of railroads, with much more of both under construction. Cities, towns and settlements were "blossom[ing] like the rose."[178]

Several of the major players left significant legacies in their adopted residences, especially in education. Sibley endowed the University of Rochester's library and founded Sibley College of Mechanical Engineering and Mechanic Arts at Cornell University in Ithaca, New York. Creighton's heirs founded Creighton University in his name in Omaha. Wade founded the Case School of Applied Technology, which later became part of Case Western Reserve University in Cleveland.

A century after completing the 1861 transcontinental telegraph, little remains. Trail expert Paul Henderson wrote about South Pass, Wyoming, in 1955, a site on the original transcontinental telegraph route that also ran along the Oregon Trail: "One often finds the stubs of the old cedar and pine poles, and tie wires. Occasionally one of the early wood shell insulators is found."[179] Years later, these remnants have been picked out by collectors or lost to time. Today, the only significant remnants of the original 1861 telegraph line are reported to be a debris scatter near Government Creek in Tooele County, Utah. This may be the remains of a booster station.[180] (See Appendix B for some examples.)

The "Utah and the Civil War" monument at the state capital honors "the Utah men who answered the call to protect the mail and telegraph lines along the continental route during the Civil War." Other local museums, national parks and monuments, and state markers along the transcontinental telegraph route contain historical displays. Road markers and signs have been posted as well. Several of the last surviving stage and telegraph stations have become historic sites, such as Platte Bridge, Deer Creek, Mud Springs, and Sweetwater.[181] A number of monuments and local museums across the country mark the transcontinental railroad and include telegraph displays.

Western Union returned to its roots when it celebrated its 2000th Western Union agent location in the United Kingdom by issuing a commemorative medallion containing a piece of the original 1861 transcontinental telegraph line (see Fig. 19). And the Institute of Electrical and Electronics Engineers, Denver Section, recognized the importance of the transcontinental telegraph and placed an IEEE Milestone at Fort Laramie in 1990. It states:

> *Between July 4 and October 24, 1861, a telegraph line was constructed by the Western Union Company between St. Joseph, Missouri, and Sacramento, California, thereby completing the first*

TO COMMEMORATE 2000 AGENT LOCATIONS IN THE U.K.
WESTERN UNION
1999/2000
WESTERN UNION
THIS SPECIALLY MINTED COIN UTILIZES PART OF THE WORLD'S FIRST TRANSCONTINENTAL TELEGRAPH LINES LAID IN 1861, IN CELEBRATION OF 2000 WESTERN UNION AGENT LOCATIONS IN THE U.K.

Fig. 19. Western Union transcontinental telegraph medallion issued in U.K. to celebrate the 2000th Western Union Agent Location, containing a piece of the 1861 transcontinental telegraph line. (Authors' collection)

high-speed communications link between the Atlantic and Pacific coasts. This service met the critical demand for fast communications between these two areas. The telegraph line operated until May 1869, when it was replaced by a multi-wire system constructed with the Union Pacific and Central Pacific railway lines.

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APPENDIX A

Transcontinental Telegraph Construction Timeline

The timeline for constructing the transcontinental telegraph has been established in numerous sources and is presented in Table A1. There are many discrepancies among sources for specific dates, e.g. diaries versus newspaper accounts describing events. The timeline presents a general summary. Any

Table A1. Transcontinental telegraph construction timeline. (Author)

WESTERN LINE	EASTERN LINE
July 4, 1858: First pole erected on line from Placerville, CA east across Sierra Nevada mountains to Genoa, NV (formerly Utah Territory)	
Aug. 1858: Line connects San Francisco and Yreka, CA (190 miles north from Marysville)	
Nov. 1858: Line connects Placerville, CA and Genoa, NV	
	Dec. 1858: Telegraph lines connect Kansas City, MO to eastern United States
Apr. 1859: California legislature approves state subsidies for an eastern telegraph line	
Mid-1859: Line reaches Carson City then Virginia City, NV	Aug. 1859: Line reaches Atchison, KS
April 3, 1860: Pony Express opens from St. Joseph, Missouri to Sacramento, California (San Francisco is reached by steamer from Sacramento)	
	Apr. 1860: Line connects Springfield to St. Louis, Bolivar, and Jefferson City, MO and extends to Fayetteville, Fort Smith, AR
June 16, 1860: Congress passes Pacific Telegraph Act of 1860 seeking bids to construct a transcontinental telegraph—Western Union is later selected from four bidders—the deadline for construction is July 31, 1862	
	Aug. 1860: Line connects St. Joseph, MO and Brownville, NE and then reaches Omaha, NE
Mid-Oct. 1860: Line reaches Fort Churchill, NV—the farthest east before the transcontinental line starts in July 1861	
	Oct. 1860: Line reaches Fort Kearny, NE
	Jan. 1861: Pacific Telegraph Company organized by Western Union to build the eastern portion of the transcontinental line from Omaha, NE to Salt Lake City, UT
Mar. 1861: All Pacific coast telegraph companies merge into California State Telegraph Company to build the western portion of the transcontinental line under the ownership of a newly formed subsidiary, the Overland Telegraph Company	
July 4, 1861: Western Union begins work on transcontinental telegraph—James Gamble leads the western crew starting in Nevada, and Edward Creighton leads the eastern crew	
Jul. 1861: Line reaches 75 miles east of Fort Churchill, NV	

differences between the sources and this summary for specific dates have not been further reconciled.

In general terms, one route was built east-to-west (the Eastern Line), and proceeded west from Omaha, Nebraska along the Platte and North Platte Rivers and followed Forts Kearney, Laramie, and Bridger, crossing the Rocky Mountains at South Pass, Wyoming, and arriving in Salt Lake City, Utah. The other route was built west-to-east, (the Western Line) and proceeded east from Sacramento (with connections to San

Table A1. (continued)

WESTERN LINE	EASTERN LINE
Aug. 1861: Line approaches Fort Kearney leaving a gap of 1,159 miles, excluding the unconnected section under construction from Salt Lake City	Aug. 1861: Line reaches Fort Laramie, WY
Sep. 1861: Line reaches Diamond Springs, NV	Sep. 1861: Line reaches 120 miles west of Fort Kearney, NE
Sep. 1861: Line reaches Ruby Valley, NV and Salt Lake City—leaving a gap of 550 miles	Sep. 1861: Line reaches Julesburg, CO—another team moves east from Salt Lake City and is 200 miles west of Julesburg
	Oct. 1861: Eastern line reaches Sweetwater, WY Station (near Independence Rock)
	Oct. 17, 1861: Eastern portions of the line are connected at Fort Bridger, WY
Oct. 24, 1861: Brigham Young sends first official telegraph message, from Salt Lake City to San Francisco, to H. S. Carpentier, president of the Overland Telegraph Company	Oct. 18, 1861: Brigham Young sends first official telegraph message, from Salt Lake City to the eastern United States, to Jeptha Wade, president of the Pacific Telegraph Company—Frank Fuller, acting governor of Utah, sends a message to President Lincoln
October 24, 1861: Transcontinental telegraph line is completed at Salt Lake City, Utah—Pony Express ends two days later—H. S. Carpentier sends telegraph to President Lincoln notifying him the line is open—Stephen Field, chief justice of the Supreme Court of California, sends first official telegraph message from California to President Lincoln	
Jan. 1862: Overland Telegraph Company consolidates into California State Telegraph Company	Jan. 1862: Beginning Nov. 1861 the line is rerouted due to Civil War—routed away from Omaha/St. Joseph, MO/St. Louis, MO and rerouted to Omaha/Council Bluffs, IA/Chicago, IL
July 1, 1862: Congress passes the Pacific Railway Act authorizing construction of a transcontinental railroad and relocation of the telegraph line to railroad right of ways	
	1864–1865: Indian War affects more than 500 miles of eastern line with significant and targeted destruction and rebuilding—western line is relatively unaffected
	Mar. 1864: Pacific Telegraph Company merges into Western Union
Jun. 1866: Western Union purchases control of California State Telegraph Company	
1868–1869: Sections of the original 1861 transcontinental telegraph line are relocated to the right of ways for the Transcontinental Railroad that is completed in 1869	
1902–1904: Sections of the 1869 telegraph line along the Central Pacific Railroad right of way (western portion) of the Transcontinental Railroad are relocated to accommodate rail rerouting	

Francisco and Los Angeles) to Placerville, across the Sierra Nevada Mountains, then continued via Forts Churchill and Crittenden to arrive at Salt Lake City.

At the time of construction in 1861, the transcontinental telegraph line traversed land that was then defined as the state of California and the Utah, Nebraska, and Kansas Territories, with areas east of these territories already incorporated into U.S. states (see Fig. A1 and Fig. A2).

Fig. A1. Transcontinental telegraph route. (Courtesy "The New Naval and Military Map of the United States," J. Calvin Smith, J. M. Atwood, map engraver, Philadelphia, PA, 1862, Library of Congress Geography and Map Division, Washington, DC).

Fig. A2. Close-up of transcontinental telegraph from Salt Lake City to Fort Kearney. (See Figure A1).

Sources

J. R. Browne, *Resources of the Pacific Slope: A Statistical and Descriptive Summary,* (New York: Appleton and Company, 1869) pp. 431–441.

J. D. Reid, *The Telegraph in America: Its Founders, Promoters, and Noted Men,* (New York: Derby Brothers, 1879).

R. L. Thompson, *Wiring A Continent: The History of the Telegraph Industry in the United States 1835–1866* (Princeton, Princeton University Press, 1947).

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A. L. Turner, *The History and Archeology of Fenelon-A Historic Railroad Camp* (Reno, NV: Bureau of Land Management Nevada: Contributions to the Study of Cultural Resources, Technical Report No. 9, 1982).

J. D. Wolff, *Western Union and the Creation of the American Corporate Order 1845–1893* (Cambridge: Cambridge University Press, 2013).

APPENDIX B

Relics of the Transcontinental Telegraph

For purposes of this article, we focus solely on representative relics directly associated with the transcontinental telegraph line. We do not address the evolution of the telegraph key, register, sounder, or other aspects of the telegraph office or the variety of other equipment used on the line, such as lightning arresters, switchboards, station connections, or other items.

Wire

Telegraph wire in the United States in the early 1860s was made of galvanized, zinc-coated iron, typically No. 9 Birmingham gauge weighing 323 pounds per mile. This heavier gauge line was replaced in sections with No. 6 wire weighing up to 570 pounds per mile, and in some instances, a steel core with an external covering of copper was also employed known as the American Compound Wire (see Fig. B1).[1]

Although copper is a better conductor, the galvanized iron provided superior ductility and strength for suspension, nearly ten times stronger than copper wire. In addition, the price of copper in

Fig. B1. A section of the 1861 transcontinental telegraph wire gifted to Creighton University by Western Union at the 1961 transcontinental telegraph centennial. (Courtesy Creighton University, Omaha in the Anthropocene Exhibit, https://steppingintothemap.com/anthropocene/items/show/4)

the 1860s was nearly ten times greater than iron. By 1884, hard-drawn copper wire began to replace the galvanized iron wire for overland telegraph purposes.[2]

American Morse telegraph systems operated on a closed circuit, meaning only one line was strung, and a grounding stake was placed into the ground at each end of the wire, with earth furnishing the return back to the battery. Operators "cut in" as they keyed and broke the closed circuit that had continuous current on the line.[3] One analysis discussed by a National Park Service historian estimates that on a hypothetical 690 mile telegraph line, such as the Promontory Point to Sacramento line, the line had at least 7,890 ohms resistance, assuming only one instrument at each end and no intermediate towns "cut in." This estimate is based on modern calculations for No. 9 galvanized wire, which is the type of wire specified for the 1861 transcontinental telegraph. Note that the chemical composition and annealing methods used to produce telegraph wire have changed. These and the environmental conditions (e.g., wet versus dry conditions and the quality of the insulator contact points with the line) all affect the rate of signal leakage. This simplified calculation also notes that a primary battery or gravity cell with about one gallon of capacity provided the only source of power. Each cell produced approximately 1 to 2 volts. Therefore, operating the 690

Fig. B2. Western Union's New York City battery room. (Courtesy *Harpers Weekly, Aug.* 1873)

mile telegraph line would have required roughly 394 battery cells (see Fig. B2). This quantity of cells increases with each station placed in the middle. The actual transcontinental line operated in shorter segments with relay stations. If four intermediate relay stations are included over a distance of approximately 260 miles, the voltage required drops to 150 to 195 volts, assuming approximately 11.4 ohms per mile for No. 9 wire. Coils in telegraph relays and sounders were generally wound to approximately 150 ohms resistance, and they were designed to operate at a line current of 0.050 amperes. The actual Omaha to Fort Laramie segment was 590 miles and would have required 307 to 384 volts. Note, these calculations reflect a modern measurement of resistance. Pope's *Modern Practice of the Electric Telegraph* dated 1869 reports 16 ohms per mile resistance for telegraph wire, versus the 11 ohms per mile in modern measurement as discussed above. In telegraph wire, the resistance is directly proportional to the length, and inversely proportional to the weight.[4]

Joining the ends was tough work and had to be done at the point in space where the wires met (see Fig. B3).[5] American telegraph systems of the era generally used two types of splices to join the wire, each laying the wires together and twisting them, then soldering the joint. The iron wire joint twists each wire around a straight segment of the other wire before soldering (see Fig. B4). Clamps were also used to simply twist the wires together before soldering (see Fig. B5).

Given the widespread replacement of most of the original 1861 transcontinental telegraph, and either reuse or destruction of the original equipment, little remains of the original telegraph wire. Some remnants have been identified or attributed to the original telegraph lines by collectors and local museums, and remnants continue to be located with metal detectors and "dug out" by collectors along the original route.

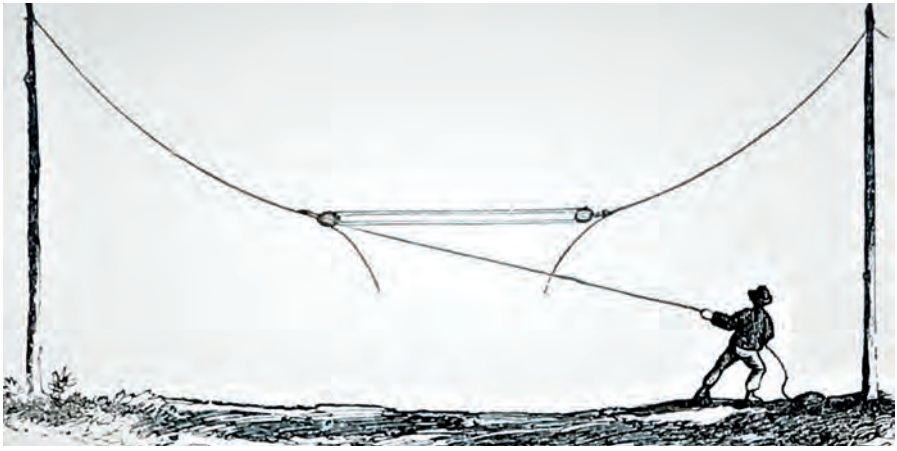

Fig. B3. Drawing the ends together to mend the telegraph line. (Courtesy Shaffner, 1859, p. 709)

Fig. B4. American iron wire telegraph wire line joint. (Courtesy Shaffner, 1859, pp. 704–705)

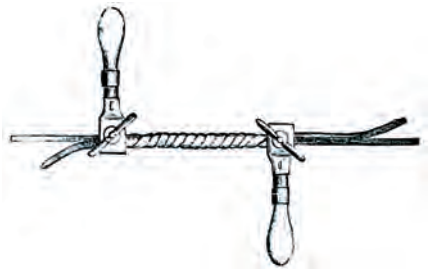

Fig. B5. American iron wire telegraph jointing clamps. (Courtesy Shaffner, 1859, pp. 704–705)

Poles

All of the equipment and poles were transported by river or wagon from the eastern United States toward the west, or from California toward the east, as construction progressed. The entire length of the line rested upon telegraph poles, and submarine cables were not used to cross rivers. Entire sections of the line traversed miles of barren plains or desert or rugged mountains. In one stretch, timber was transported 240 miles.[6] In a different stretch of the Sierra Nevada, poles were transported 300 miles at a cost of 4 to 6 cents per pound for freight. Overall, the cost of transportation was the most expensive item.[7] Poles were obtained from farmers, ranchers, other local suppliers, and the army often hewed and hauled their own poles.[8]

From 20 to 40 poles were placed each mile depending on the terrain (see Fig. B6). Although many types of trees were used on telegraph lines in the eastern United States, more than half of all poles on the transcontinental line were made from white cedar, with the remainder mostly made from pine. The California sections utilized Pacific Coast redwood and pine. They were stripped of bark and smoothed but not painted and could last up to 25 years.[9]

Poles were generally 22 to 25 feet in length with a diameter of at least 5 to 6 inches at the top, and were set 4 to 5 feet into the ground, depending on the soil, and were braced in soft soils. In the mountains, poles were up to 40 feet in length to accommodate the great depth of seasonal snow accumulations. They were also placed closer together to prevent the wire being broken by an accumulation of snow and sleet. Poles were also spaced closer when subjected to extremes in annual weather conditions between summer and winter, which caused the telegraph line to shrink or expand by up to 4 feet per mile in length.[10] The poles themselves were generally square cut, but round diameter poles were also used.[11]

Initially, the transcontinental telegraph only utilized poles that each had a single mounted insulator to suspend the telegraph line. Crossarms were later used when multiple lines were needed, and to separate railway telegraph lines from commercial telegraph lines when the original transcontinental line was relocated over to the railroad right of ways. Crossarms were generally made from seasoned white pine.[12] By at least 1868, telegraph lines along the transcontinental railroad had poles with a single crossarm and two ramshorn insulators inserted on the underside.[13]

The number of poles did not markedly change when portions of the original 1861 transcontinental line were relocated along the 1869 transcontinental railroad, and averaged 35 poles to the mile.[14] Given the widespread replacement of most of the original 1861 transcontinental telegraph line, and either reuse or destruction of the original equipment, little remains of the original poles. Some poles and remnants have been identified or attributed to the original telegraph lines by collectors and local museums.

The basic tools utilized in pole cutting, pole preparation and carrying,

Fig. B6. Installing telegraph poles. (Courtesy *Harpers Weekly*, Nov. 2, 1867)

manual pole digging and installation, and pole climbing and telegraph wire stringing remained generally unchanged through the 1880s until the advent of steam driven pole digging equipment (see Fig. B7 and Fig. B8).[15]

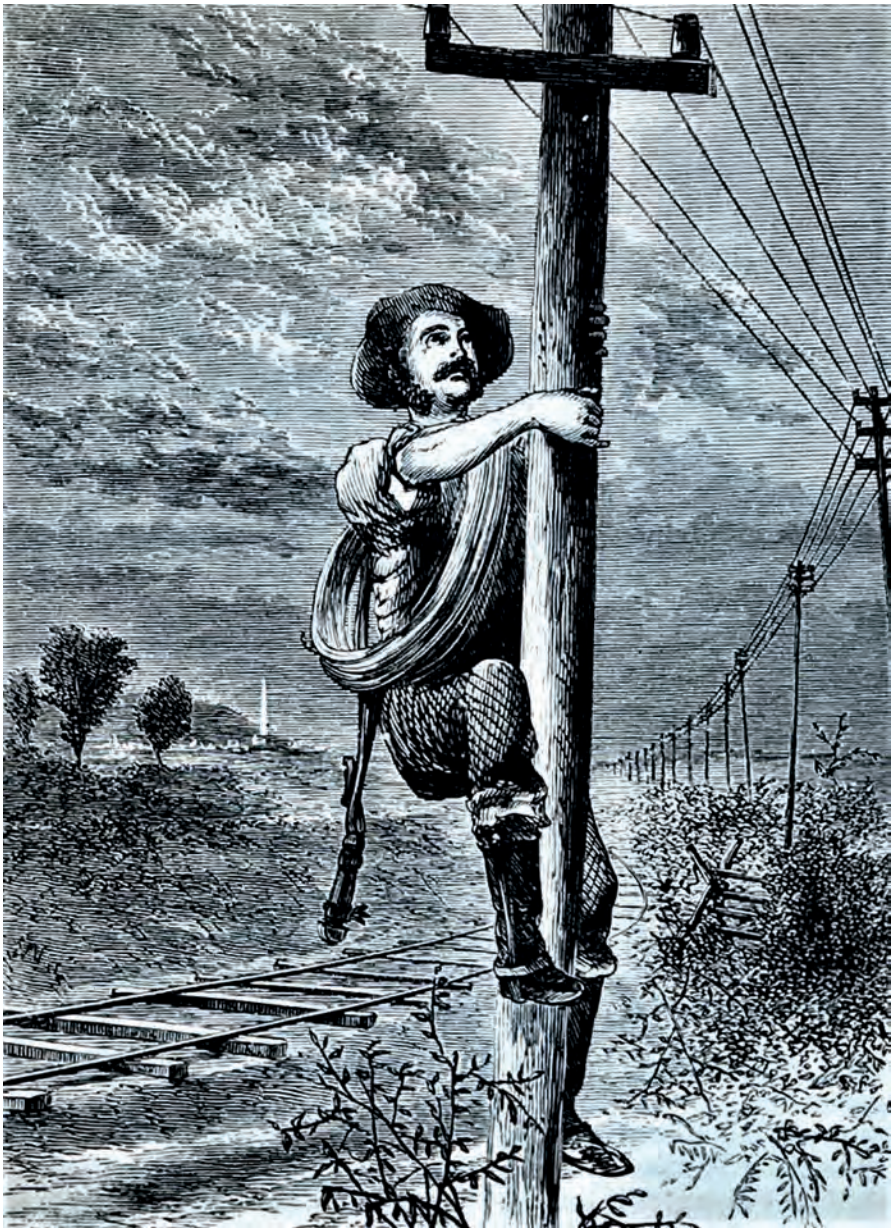

Fig. B7. Telegraph pole climbing. (Courtesy *Harpers Weekly*, Aug. 1873)

Fig. B8. Tintype of telegraph lineman circa late 1860s. (Authors' collection)

Hicks Repeater and Relay Stations

The telegraph repeater, or translator, was instrumental in extending telegraph service over long distances. The repeater receives an incoming message from one wire and relays it automatically to another wire, eliminating the need to manually retransmit the signal. So, the repeater essentially transfers the signal message from one section onto a new section of the line. Repeaters could be placed at intervals along the telegraph line in unmanned stations. The repeaters received an incoming electrical signal and then automatically repeated the signal on the next section of the telegraph line under new battery power. Distance between stations was determined by the batteries, resistance of the telegraph line, and the ability to detect the weakening signal strength before it was depleted.

Moses Farmer and Asa Woodman developed the first practical automatic repeater for use on American telegraph systems in 1856. In 1858, George Hicks developed a new, more efficient, button-type repeater, where the circuits were opened and closed directly by the repeater rather than the sounder. James Clark modified the Farmer and Woodman concept by placing additional local magnets into the circuit that better separated the incoming and outgoing circuits. Hicks returned with a magnetic adjusting repeater in 1862, employing a different arrangement of the Clark battery circuits to further improve the operation of the levers and relays. In 1864, G. F. Milliken further developed the Hicks concept by using auxiliary local magnets and armature springs independent of the relay itself, permitting the use of stronger springs and achieving an overall sharper action.[16]

The construction plans for the transcontinental telegraph specified use of either the Hicks or the Farmer and Woodman repeaters and 25 poles per mile (see Fig. B9).[17] The original 1861 transcontinental line, re-routed in January 1862, utilized Morse instruments, direct from Chicago to Salt Lake City, with Hicks self-acting repeaters located at Omaha and Fort Laramie. The messages were rewritten at Salt Lake City, and then sent direct to San Francisco. The actual distance between telegraph stations averaged about fifty miles per station. The entire length of the line was inspected twice each week. The actual cost of construction was about 250 dollars per mile.[18]

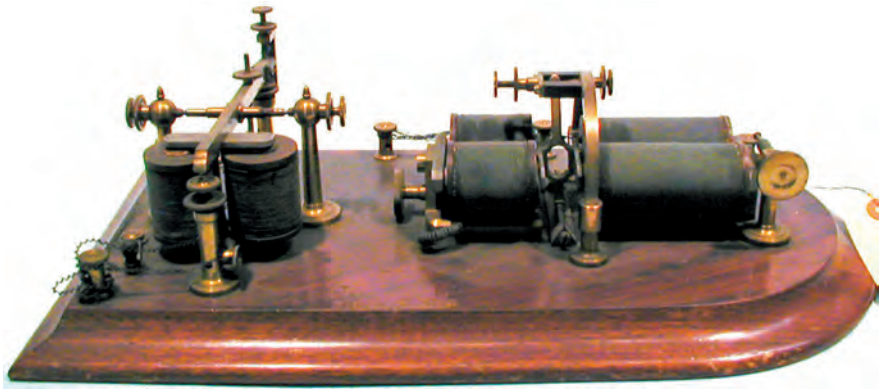

Fig. B9. Patent model for the Hicks telegraph repeater, U.S. Patent No. 34,574 dated March 1862. (Courtesy Smithsonian Institution, National Museum of American History, Object EM.251255)

In February 1868, tests were performed for the U.S. Coast Survey in connection with their work measuring longitude using telegraph signals. Lines were connected from Cambridge, Massachusetts to San Francisco, California, and back, using 13 repeaters to cross the 7,000 miles of roundtrip distance. The actual time of transmission from Cambridge to San Francisco and back was estimated not to exceed 3/10 of a second, and the armature times of the 13 repeaters were estimated at four or five tenths of a second.[19]

A widely used 1912 telegraphy encyclopedia noted that the Millikan variant of the Hicks repeater became an industry standard, and was considered by many to be one of the best repeaters known.[20]

Insulators

Telegraph wire suspended on the poles were attached to insulators, and not directly to the poles, to prevent the current from escaping to earth at each point. Insulators, made of glass, hard rubber, or porcelain, are attached to the poles with mountings, or pins. Since the telegraph wire touched each insulator, each insulator represented a point of contact for leakage to occur. With approximately 30 to 40 poles per mile, this represented 30 to 40 points of potential signal leakage in each mile. For a line of 100 miles, the presence of 3,000 to 4,000 points of leakage represented significant risk of signal depletion, necessitating the careful selection and installation of appropriate insulators. Insulator collectors have developed considerable historical research and a comprehensive classification of insulators as well as an active collectors' market for these items.[21]

Glass Insulators

Threadless glass insulators were used from the late 1850s through the end of the Civil War. These insulators simply pushed onto a wooden pin that mounted to the pole. Each insulator was held onto the pin with friction or a binding agent, such as molten sulphur and a piece of

burlap, or asphalt. Over time, the mixture would dry and the burlap would shrink, allowing the insulator to break free of the pin, rendering it less effective or completely broken. In 1849, J. J. Speed developed a wood-covered, threadless, glass insulator. Jeptha Homer Wade, later one of the original founders of Western Union, modified the design, and the new "Wade Insulator" became widely promoted in the 1850s and 1860s. The Wade Insulator was specifically selected for the eastern portion of the transcontinental line.[22]

The Wade Insulator had a glass cylinder that inserted into a wood covering or shell that was coated with coal tar, which preserved the wood (see Fig. B10). The glass was either smooth (CD 723.3 per the insulator collector classifications) or had small projections to help grip the wood cover (CD 723, sometimes called the dot-dash sleeve design). Tar was also inserted at times between the wood and the glass as an adhesive.[23] Threadless insulators began to be replaced by threaded insulators after 1865, and became obsolete over the next 5 to 6 years.

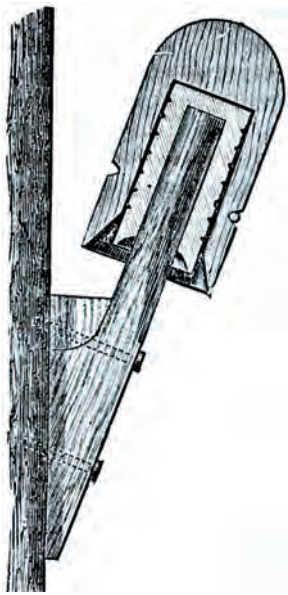

Fig. B10. Wade type insulator showing the internal glass sleeve and the external wood shell mounted onto a threadless wooden pin and affixed to a pole. (Courtesy, Pope, 1869, p. 60)

As early as 1862 and certainly by 1868, portions of the original 1861 transcontinental telegraph line were rerouted along the new transcontinental railroad right of ways.[24] Multiple types of glass insulators were used along the Union Pacific Railroad (UPRR) route. Charles and John Chester were well known telegraph equipment suppliers in New York who developed a variety of glass insulators, including threaded insulators. Mulford and Biddle was another New York supplier who developed their own glass insulators that were used along the UPRR route. In Nebraska Territory, a Chester type 735 insulator was used, with the CHESTER name embossed in the glass. In Wyoming and Utah, Mulford and Biddle types CD 735 and CD 735.3 insulators were used across the mountains, with MULFORD & BIDDLE UPRR name embossed in the glass. Beginning 1875, the California Pacific Railroad (CPRR) utilized Electrical Construction & Maintenance Company (EC&M) glass insulators made in San Francisco, California, for their re-routed telegraph lines and to replace their original ramshorn insulators, since those were less efficient electrically than glass insulators and were more prone to

attract lightning because of their metal construction.[25] Significant telegraph reroutings occurred in at least 1868–1869 and again in 1902–1904 when the CPRR engaged in major realignment construction.[26]

In 1864, several telegraph companies merged to form the United States Telegraph Company, which itself later merged into Western Union in 1866. The company built portions of the rerouted transcontinental telegraph line west of Salt Lake City and near Sacramento and utilizing glass insulators marked "U.S. TEL. CO." of the CD 735.3 type.[27]

In addition, after the Civil War, several companies manufactured a "compromise" style insulator (CD 731), including McKee, Tillotson, Brookfield, and other glass companies. Insulator collectors found many CD 731 insulators along the UPRR route in Wyoming and Utah, both un-embossed and with the "S. McKEE & CO." embossing. Most found along the UPRR right-of-way were likely used by a commercial telegraph company. They were placed on poles on the opposite side of the track from the UPRR's telegraph line, which used the CD 735 Mulford and Biddle insulators or later the McKee embossed CD 731 type insulators (see Fig. B11).[28]

Ramshorn Insulators

In 1858, M. G. Farmer and J. M. Batchelder received a patent for a new type of underhung, hanging type insulator mounted in a wooden block, the so called "ramshorn" insulator. (Note, ramshorn is a more modern term for these insulators. In the 1860s, these iron hook insulators were denoted by their manufacturer or patent holder names.) Ramshorn insulators hung down from their mounted position, versus the glass insulators described above that were lodged onto a post that mounted to the pole or crossarm so the insulator resided above, or protruded out, from the pole or crossarm. The wood blocks that held the ramshorn

Fig. B11. Recovered transcontinental telegraph glass insulators, all threadless (left to right): Wade internal glass sleeve, EC&M, Mulford and Biddle, and an early flat-top concave-skirt threadless CD-731. (Authors' collection)

insulator were made in tapered or square shapes that were mounted to poles, or to trees with the line running from tree to tree (see Fig. B12). The ramshorn, made of a metal hook, typically iron, was itself coated or mounted into hard rubber (gutta-percha) or asbestos (see Fig. B13). It came in many styles and had various markings over the years, often associated with the Goodyear patent of 1861, the Marshall Lefferts patent of 1849 with the hook embedded in glass, or the original Farmer and Batchelder patent of 1858 with the hook encased in hard rubber. The hook variously screwed or inserted into the wood block or into a glass sleeve that was inserted into the block or into a telegraph pole crossarm.[29]

In 1867, David Brooks obtained a reissued patent (the original was dated 1864) for a modified ramshorn insulator where an iron hook inserted into a long glass sleeve that fit into a metal outer shell. The components were held together with molten sulfur (see Fig. B14). Several variants with different markings were produced, most with Brooks name, some with CPRR, and most with a patent date of August 6, 1867; some had no markings. They were also produced in varying lengths or had modified outer shell shapes.[30] The UPRR and Western Union also used Brooks insulators on the eastern portion of the transcontinental railroad when they relocated portions of the original transcontinental telegraph line.[31]

Fig. B12. Mounting a telegraph insulator bracket onto a pole or tree. (Courtesy Shaffner, 1859, p. 710)

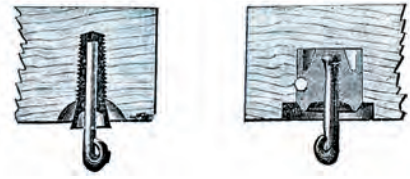

Fig. B13. Ramshorn type insulators showing the hook mounted into a crossarm or wooden block. (Courtesy, Pope, 1869, p. 60)

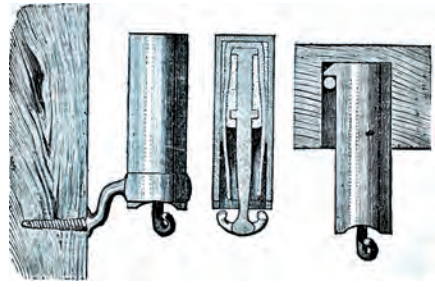

Fig. B14. Brooks type insulator (left to right): mounted onto a steel pin affixed to a telegraph pole, the internal design with the internal metal hook/post and the glass sleeve inside the external metal housing, mounted into a wooden crossarm. (Courtesy, Pope, 1869, p. 61)

Ramshorn insulators were widely used on the Overland Telegraph Company's 1861 transcontinental telegraph; primarily with Farmer and Batchelder patents, mounted in various wedge shaped wooden blocks that were nailed with square nails into trees (see Fig. B15). CPRR utilized various underhung insulators, especially Brooks' ramshorn insulators (see Fig. B16). Beginning in 1875, these were replaced by EC&M glass insulators as noted above.[32]

Endnotes

1. G. B. Prescott, *Electricity and the Electric Telegraph,* (New York: D. Appleton and Company, 1885) Vol. 1, p. 298; F. L. Pope, *Modern Practice of the Electric Telegraph: A Handbook for Electricians and Operators,* (New York: D. Van Nostrand, 1869, 2nd ed.) pp. 89–90.
2. W. Maver, *American Telegraphy and Encyclopedia of the Telegraph,* (New York, Maver Publishing Company, 1912) pp. 509–510.
3. Maver, 1912, pp. 54–56. Note: Thomas Edison and George Prescott developed quadruplex telegraphy in 1873–1874. Western Union obtained patent rights to use the new technology in 1874. See *Western Union Report to Stockholders*, 1873,

Fig. B15. Transcontinental telegraph, Farmer and Batchelder type, ramshorn insulator and wood mounting block with square-head mounting nails and pliers, recovered from the Sierra Nevada Mountains near the Lake Tahoe Basin. (Authors' collection)

Fig. B16. Transcontinental telegraph, Brooks patent insulators showing a separately recovered internal hook, recovered along the CPRR route west of Promontory in the Sierra Nevada Mountains. (Authors' collection)

pp. 16–17 and *Western Union Report to Stockholders*, 1874, pp. 13–14. These methods of telegraphy permit multiple signals to be sent over a single line. The quadruplex method combined a diplex that permitted multiplexing of two signals in the same direction, which Edison had previously invented, with a Stearns style duplex that allowed simultaneous bi-directional communication. See Maver, 1912, chapters XI, XII, XIII, and XVI.

4. "Telegraph Line to Promontory," CPRR Discussion Group – Central Pacific Railroad Photographic History Museum, July 24, 2005, http://discussion.cprr.net/2005/07/telegraph-line-to-promontory.html; Pope, 1869, pp. 24–25.
5. T. P. Shaffner, *The Telegraph Manual: A Complete History and Description,* (New York: Pudney & Russell Publishers, 1859) pp. 706–707; Maver, 1912, pp. 545–546.
6. Pope, 1869, p. 40.
7. J. R. Browne, *Resources of the Pacific Slope: A Statistical and Descriptive Summary,* (New York: Appleton and Company, 1869) pp. 433–434.
8. J. Schwoch, *Wired Into Nature: The Telegraph and the North American Frontier,* (Urbana: University of Illinois Press, 2018) p. 29.
9. Pope, 1869, p. 40; Prescott, 1885, pp. 294–296; Schwoch, 2018, pp. 27–32; Browne, 1869, pp. 433–435.
10. Pope, 1869, p. 40; Prescott, 1885, pp. 294–296; Browne, 1869, pp. 433–435.
11. A. L. Turner, *The History and Archeology of Fenelon A Historic Railroad Camp Technical Report No. 9,* (Reno, NV: Bureau of Land Management of Nevada, Contributions to the Study of Natural Resources, 1982) pp. 22–23.
12. Prescott, 1885, p. 295.
13. Turner, 1982, pp. 22–23; G. Kraus, *High Road to Promontory: Building the Central Pacific (now the Southern Pacific) Across the High Sierra* (Palo Alto: American West Publishing Company, 1976); L. R. Mayer and K. E. Vose, *Makin' Tracks: The Story of the Trans-Continental Railroad in Pictures and Words of the Men Who Were There,* (New York: Praeger Publishers, 1975) pp. 208–209.
14. *The Telegrapher*, May 15, 1868.
15. See the following for discussion of pole installation tools and techniques: Shaffner, 1859, pp. 668–687, 704–717, and Maver, 1912, pp. 532–548.
16. Prescott, 1885, pp. 459–477; G. B. Prescott, *History, Theory and Practice of the Electric Telegraph,* (Boston: Ticknor and Fields, 1866) pp. 486–496.
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David and Julia Bart

History of FM Radio: 1940s to 1960s

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Howard Armstrong's first major invention, regeneration, or the feedback circuit, filled an immediate need for amplification in wireless radio receivers. It's acceptance and use by license holders was also immediate. Howard Armstrong's fourth major invention, wideband Frequency Modulation (FM), took many years to create and many more years to develop into commercial reality. The path to commercial acceptance by the radio industry would be slow and painful; very slow and very painful.

FM Development in the 1930s

Armstrong's work leading to wideband FM radio began with his work to overcome static in AM radio. He recognized the problem soon after his work on the regenerative circuit and before WWI. The result of that work was first demonstrated in 1933. Two rooms full of circuits and over 100 vacuum tubes were needed to transmit and receive the first wideband FM transmission. With no commitment but some support from RCA, he began developmental work on his system. After a short time, Armstrong decided he would have to go it alone to produce a commercial FM system. These highlights are a brief summary of a decade-long struggle by Armstrong to produce a static free radio system.[1]

- 1930–1933 Armstrong's research leads to the concept of wideband FM.
- 1933 Armstrong builds first prototype and demonstrates to David Sarnoff and RCA.
- 1934–1935 Sarnoff allows use of RCA's Empire State Building transmitter for FM tests.
- 1935 Armstrong is asked to end testing and decides to develop FM on his own.
- 1936 Armstrong discloses FM to radio industry and demonstrates FM at a meeting of the Institute of Radio Engineers.
- 1937–1938 Armstrong builds experimental FM station W2XMN in Alpine, NJ.
- 1939–1940 Other experimental stations are on the air and FM relays create a network.

During this first half of the 1930s, Armstrong hoped that RCA and Sarnoff would come to an agreement with him to purchase his FM patent rights and bring FM to a commercial version. This never happened. Instead, it appeared that RCA would deny that FM was ready and suggest delays for further testing. Contemporary studies of the radio industry tell us of the status of the relationship between RCA and FM proponents: "A significant feature of FM's introduction is the bitterness and animosities which have been aroused between its

sponsors and RCA. FM advocates are convinced that RCA, either by its apathy or by a carefully planned resistance to FM, was opposed to this new system of broadcasting."[2]

This would be the way that lines were drawn for the second half of the 1930s. But Armstrong was determined to bring FM from the point of development after the Empire State field testing to commercial success without the help or cooperation of RCA. As his experimental station went on the air in 1938, Armstrong reported that he had invested between $700,000 and $1,000,000 of his own funds. This would be approximately $14,000,000 in 2021 dollars. The 1930s would end with a few experimental FM stations on the air. A total of seven experimental stations were on the air in 1939, increasing to eleven in 1940.

Armstrong and the proponents of FM rang in the 1940s on a positive note. He granted licenses for receiver manufacturers and broadcast equipment manufacturers. FM broadcasting had been assigned to the 42–50 MHz band and radio enthusiasts were beginning to buy receivers (Fig. 1). Radio listeners, that already owned a high-quality receiver, could purchase FM converters to allow reception of FM stations that could be played through the existing radio's amplifier. One such unit from E. H. Scott, called their FM Tuner, (Fig. 2) had no audio amplifiers and was attached to the console radio's phono input. Royalty payments slowly came in to Armstrong's accounts. By the 1940s his expenses totaled over $1 million and he had only realized some $500,000 in royalties. In 1941 the first commercial stations are authorized; these are shown in Table 1.[3]

John Shepherd III, a New England entrepreneur and FM proponent, was

Fig. 1. Stromberg-Carlson model 505H pre-war FM radio, 1940. (Author's Collection)

Fig. 2. E. H. Scott pre-war FM tuner with output for an audio amplifier. (Author's Collection)

Table 1. Commercial stations "On the Air" May 1941. (Author)

W51C	Chicago, IL
W55M	Milwaukee, WI
W39B	Mt. Washington, NH
W47NV	Nashville, TN
W71NY	New York, NY
An additional 44 stations had construction permits granted	

building a network of stations around New England. His broadcasting stations were to be joined by FM relay stations. Armstrong soon granted licenses to more broadcasters as the FCC granted more construction permits. Armstrong worked closely with the manufacturers of broadcast equipment and the manufacturers of home receivers. He was always cautious to license companies he felt would meet his standards. Soon more commercial broadcasters were authorized. Those on the air in July 1942 are shown in Table 2.[4]

The year 1941 began with a positive note for the proponents of FM. After nearly a decade of personally financing the development of FM, Armstrong finally saw income from his patents. Royalties were coming in, but they were still well below his expenses. General Electric, Zenith, Stromberg-Carlson, Westinghouse, and some others had

Table 2. Commercial FM stations "On the Air" July 1942. (Author)

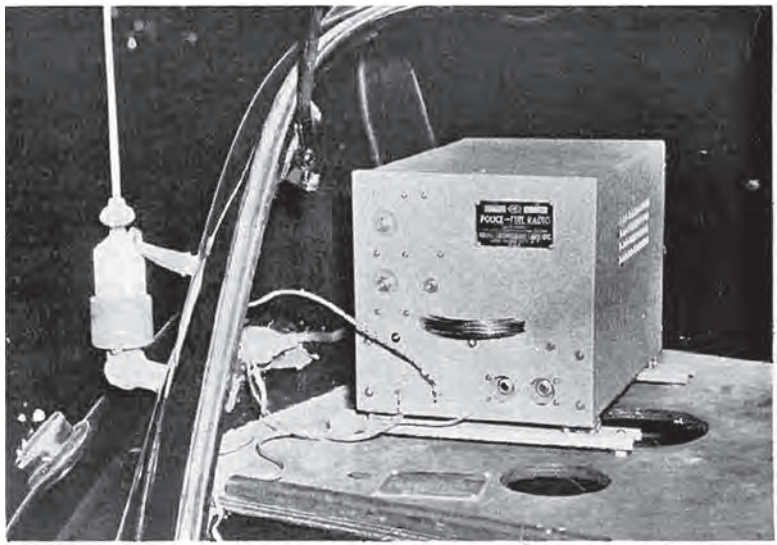
K45LA	Los Angeles, CA		W67B	Boston, MA		W45CM	Columbus, OH
W53H	Hartford, CT		W45D	Detroit, MI		W49PH	Philadelphia, PA
W65H	Hartford, CT		W49D	Detroit, MI		W53PH	Philadelphia, PA
W51C	Chicago, IL		W39B	Mt. Wash. NH		W69PH	Philadelphia, PA
W59C	Chicago, IL		W47NY	New York, NY		W47P	Pittsburgh, PA
W67C	Chicago, IL		W67NY	New York, NY		W75P	Pittsburgh, PA
W45V	Evansville, IN		W71NY	New York, NY		W47NV	Nashville, TN
W45BR	Baton Rouge, LA		W47A	Schenectady, NY		W55M	Milwaukee, WI
W43B	Boston, MA		W51R	Rochester, NY		*	
* 10 additional stations were broadcasting with experimental licenses.							

become believers in the benefits of FM. Business projections in the industry were for continued growth. In 1942, still more applications for FM broadcasting licenses were being submitted to the FCC.

Other developments were also showing positive results. FM multiplexing, the transmitting of more than one signal on the same carrier, showed great promise. There was commercial interest in this technique to provide subscription service, such as Muzak, as an add-on to an existing station. There was also great interest in the use of FM radio relays as a method of sending quality audio from point to point. This could be used to allow program sharing between stations without having the high cost of renting lines from AT&T. The Yankee Network soon put this into use sending programming to their transmitter atop Mt. Washington in New Hampshire and other stations in New England.

The use of FM showed great benefits over the use of AM in mobile 2-way communication. Increased coverage and improved clarity encouraged testing and was soon adoption by state police and emergency service organizations (Fig. 3). Companies like the Fred M. Link Company would build their businesses around FM communications gear. Their equipment was used to outfit the Connecticut state police and other emergency services in 1941. They also produced equipment for use by radio and news reporters to send reports from live events back to their station or newspaper (Fig. 4).

In 1943 Armstrong was asked to predict the future for FM as the end of the world war was in sight. His response was reported in *Broadcasting* magazine.



PERFORMANCE OF THIS F-M TRANSMITTER EARNED R.E.L. AN ORDER FOR 200 LIKE IT

POLICE RADIO WITH THIS F-M TRANSMITTER, R. E. L. MADE POLICE RADIO HISTORY IN CHICAGO

Fig. 3. REL ad showing that FM communications have been used to improve police and emergency services radio. (*FM Magazine,* Nov. 1940, p. 14)

SPOT COVERAGE WITH Link FM MOBILE RELAY BROADCAST SYSTEM
BROADCASTING STATION
TELEPHONE LINE
IF YOU CAN DRIVE TO IT—HERE IS THE BEST PRACTICAL ANSWER TO BROADCAST QUALITY COVERAGE OF OUTDOOR EVENTS
RESCUES
SPORTS
DISASTERS
PARADES
WIRE—WRITE OR PHONE
Fred M. Link
PREFERRED FM RADIO COMMUNICATION EQUIPMENT

Ads for F.M. Link Communications Equipment

Fig. 4. Ads showing that *FM Magazine*, outside of broadcast radio, has become a big business and the Fred M. Link Company is a leader. (*FM Magazine*, left picture, back cover July 1946, right picture, inside back cover Feb. 1941)

He believed FM would pick up right where it left off. Not only would the construction of new FM stations and the production of receivers grow, but also the use of FM relay stations would have an expanding impact on broadcasting. Finally, he closed with a bold prediction, "The conclusion is likewise inescapable that within five post-war years the existing broadcast system would be largely superseded."[5] He had no way of knowing how hard powerful interests would work to make sure that would not happen.

The problems encountered with getting FM used on the radio spectrum can be separated into the following categories. These are elaborated in the following sections:

- Campaign to Avoid, Deny, and Delay FM
- Challenge presented by World War II
- Competition with Television
- Battle of Regulation
- Battle of Patents
- Battle of Litigation
- Test of Endurance

The Campaign to Avoid, Deny, and Delay FM

As the 1940s began, Howard Armstrong and the proponents of FM had already faced many challenges. The economic depression of the 1930s slowed much progress in radio including the advancement of FM broadcasting. In the 1933 FM demonstration, Sarnoff and RCA engineers heard static free high-fidelity sound from an apparatus using hundreds of tubes to make an FM transmitter that filled one room, broadcasting to a receiver filling the next room. No one would argue that Sarnoff should take a wait-and-see attitude in the beginning. Sarnoff did permit Armstrong to conduct field tests from the Empire State building, but Sarnoff's attitude never changed. Armstrong waited for a positive sign that RCA would move ahead with FM development. It began to appear, during the 1934 field tests, that the more positive results reported from the FM field testing, the cooler the reception from RCA management. Growing frustrated, Armstrong pressed for a meeting with David Sarnoff. That meeting was finally arranged in the summer of 1934 when Sarnoff returned from an overseas trip. Armstrong later would testify as to the details of the conversation.[6]

> "Why are you pushing this so hard?" asked Sarnoff.
>
> "There is a depression on," said Armstrong, "The radio industry needs something to put life in it. I think this is it."
>
> "Yes, said Sarnoff, but this is not an ordinary invention. This is a revolution."
>
> "That is all the more reason to get it into use as fast as we can," replied Armstrong.

Sarnoff changed the subject and no commitment was made. Sarnoff did make a trip to hear a demonstration of the field test transmission. He then stated he would soon form a committee at RCA to update him on the state of television and FM. No report was completed. A number of things could explain Sarnoff's actions to delay and deny:

- Sarnoff didn't want to see all of the AM broadcast stations become obsolete.
- Sarnoff didn't believe the public would accept that all of their AM radios would stop working.
- RCA couldn't afford the extra expense of developing FM during the depression.
- It was obvious that the FM system needed to be simplified.
- Sarnoff did not want to see AM broadcast advertising income shared with FM.
- Most of all, Sarnoff wanted nothing to impede the development of television.

In the spring of 1936, the FCC held hearings to determine the needs for new frequency allocations to provide for radio growth and future development of television. At the hearing, Armstrong spoke up for FM allocations. RCA and Sarnoff presented the bandwidth needs of television. As the RCA presentation concluded, there was no mention of FM. Armstrong could only conclude that RCA wanted to deny the existence of FM. The inaction of David Sarnoff to become active in supporting FM reinforced Armstrong's conclusion to develop and test FM with his own funds. Sarnoff had often spoken of his views regarding inventions and innovations. He believed that a corporate leader would have to determine if a new invention would enhance or supplant a company's products. If he determined the new invention could supplant his product, he would be obliged to act on the new product or have his business fall behind. If he determined it was an enhancement to a product, he could move more slowly and incorporate enhancements to his products over time. As Armstrong moved ahead developing FM on his own and perhaps because he saw the progress Armstrong was making, Sarnoff would make an offer to buy the FM patents. He offered a single payment of $1 million for full rights to all of the FM patents, including the right to license other companies. Armstrong angrily turned him down. He thought it would be unfair to other license holders to give RCA this special deal. They had their chance for a special deal years ago and declined. Now RCA would have to pay the license fees like everyone else.

With no license, Sarnoff chose to treat FM as an enhancement to AM radio, one that the corporation could choose not to pursue or gradually incorporate into their business. He could choose to see FM as an evolution of radio but he saw Armstrong's approach as demanding a revolution. Perhaps Sarnoff viewed his earlier purchase of the rights to Armstrong's super-regeneration patents as a mistake, one mistake he would not repeat. Super-regeneration[7] was to start a revolution in radio manufacturing. If it lived up to its potential, the circuit would allow the patent holder to manufacture a sensitive receiver at a very low cost. Unfortunately for Sarnoff, technical issues prevented it from becoming a commercial success. Sarnoff's experience with super-regeneration may have contributed to his decision to put off a commitment to FM development. When Sarnoff saw the rooms full of circuits in the first FM

demonstration, it could be viewed as another invention that may never bring a return on investment. If he understood FM to be enough of an innovation that AM radio would be superseded, and the industry would be disrupted with an abrupt changeover, then Sarnoff could not let that happen.

The actions against FM by RCA and other industry leaders had an impact throughout the industry. Having suffered through hard economic times, many in the radio business from broadcasters to manufacturers to retailers had feared what a major change might bring. An article in *Radio Retailing* in 1935 sought to reassure worried sales and service dealers stating that FM, if it did come along, would be by a slow transition.[8] By the 1940s, this was changing; the dealers were anxious to add more to their lines. There could not have been much profit margin left as AM radio prices had fallen so low. A new product that would encourage new buyers must have been a welcome sight.

Armstrong continued his effort to promote FM with public demonstrations and appearances before FCC committees (Fig. 5). It was becoming obvious to all that Armstrong and FM had become almost a single entity. A victory or setback to one was felt by the other. They would need to join their strength to fight these challenges still ahead.

Although the effort by Sarnoff and RCA to delay FM continued as the 1940s began, Armstrong's campaign to educate the public about the benefits of FM began to take hold. Demonstrations by Armstrong and other proponents like The Yankee Network were well received. The Yankee Network's demonstration unit travelled around their region (Fig. 6). Other networks of FM broadcasters formed, such as the American Network and the Colonial Network. Also, another organization was formed, FM Broadcasters Incorporated, FMBI, to lobby as a group for the benefit of their members. At first the response from RCA and the opponents of FM was to continue denying that FM was ready for commercial use. In 1939 a hearing was held at the FCC to decide if FM was ready for the change from experimental FM broadcasting to commercial FM broadcasting. Armstrong appeared ready to vigorously defend FM from the usual attacks by RCA. To everyone's surprise, the spokesman for RCA said that FM was ready for commercial use and that its subsidiary the National Broadcasting Company, (NBC) would begin adding a FM broadcast service to their NBC stations. Manufacturers were now producing table radios with both the AM and FM band (Fig. 7).

The next surprise was that Armstrong soon found out that this new attitude did not bring RCA to the table ready for a license. But, by this time, Armstrong and the radio industry and the entire nation was hearing a new call. World War II would put all of the squabbles over FM on hold, as the nation would need industry cooperation for radio technology to help win the war.

Fig. 5. Armstrong, shown here, traveled with The Yankee Network and others to demonstrate the benefits of FM. (Armstrong Family Archive)

Fig. 6. The Yankee Network runs a FM demonstration tour around New England. Shown is their transmitter trailer pulled by an attention-getting car. (Poppele Collection FM Scrapbooks, AWA Museum)

Fig. 7. Pilot model T-301 pre-war AM-FM radio, 1941. (Author's Collection)

The Challenge presented by World War II

A short time after the attack on Pearl Harbor, restrictions were placed on the radio industry. There would be no production of home radios and no construction of new FM stations. Payments from patent royalties were stopped. Armstrong, who had already battled through the worst years of the depression and was in a battle with the men and corporations of the radio industry, would now suffer financial hardship due to the war effort. While some might think that now the gods are lining up against him, that was not Armstrong's way. Still called "The Major" in honor of his service in World War I, he volunteered his service and the service of the laboratory to help the war effort. Unlike others in the industry, Armstrong did not charge the government for his time or expense or the use of his patents. He made it official, sending a letter to Secretary of War Henry L. Stimson, dated March 10, 1941, waiving all royalties on FM equipment. RCA, by comparison, had many government contracts to produce equipment and continued to charge patent royalties. When pressed on the issue, David Sarnoff gave the government a discount charging a one-time license fee of $4 million.

Although not serving in uniform, The Major was answering his country's call to duty. Primarily Armstrong and his staff worked for the military in two areas: ground FM communication and FM-based radar. As a radio researcher, Armstrong was aware of radar and its importance to the war effort. The first radar systems used a pulsed AM signal

and had limited range. As new aircraft moved faster and faster, increased range was needed for more warning. As always, he was confident that another approach should be investigated. Since FM signals had proven to have far better coverage than AM signals, he proposed building a system using a continuous wave FM signal. Armstrong had to increase his staff, now 18 people, and his payroll, which had been $50,000, to $100,000 per year, again at his personal expense.[9] One of the newly hired, a young recent graduate, Robert E. Hull, was assigned to be a project engineer for radar research. A SCR-271 radar antenna was erected at the Alpine station for experimental use, material and components were purchased, and Armstrong and his staff began to construct the needed equipment (Fig. 8).

(left)
Armstrong at his desk at W2XMN, Alpine, NJ

(bottom left)
SCR 271 radar antenna erected at Alpine, NJ for experimental work

(bottom right)
Equipment racks for FM RADAR tests Alpine, NJ

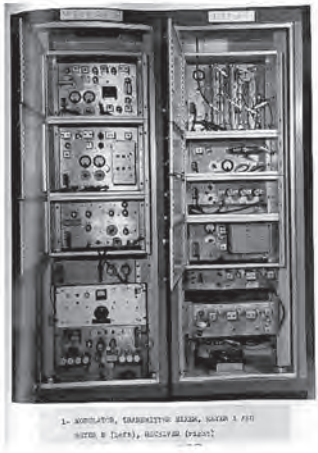


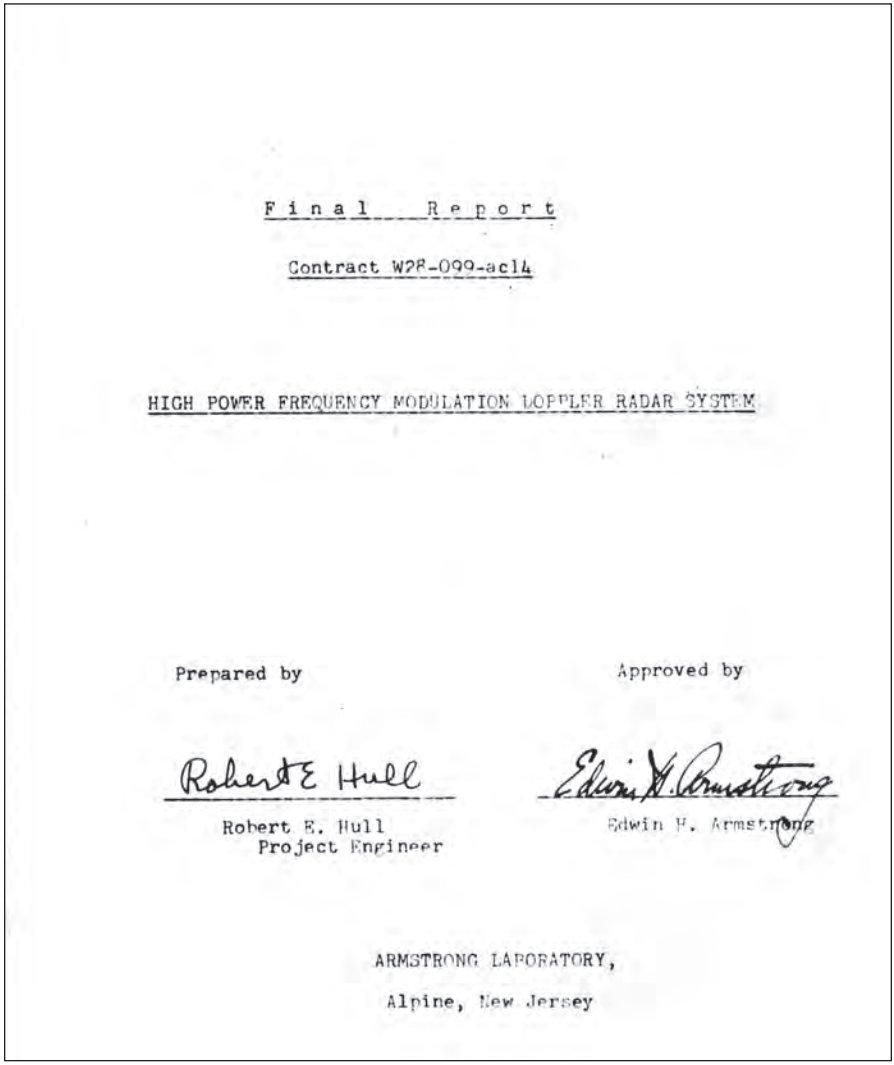
Fig. 8. Armstrong conducts FM radar experiments at the Alpine Station. Shown here are Armstrong at his desk, the SCR-271 radar antenna, and equipment racks at for experimental work at Alpine, NJ. (Armstrong Archive, Columbia University Library)

Still, with all of the effort Armstrong put into the war effort, he refused to bill the government for his work and refused to bill the government for patent royalties. As war restrictions continued to prevent the sale of home radios, royalty income to Armstrong remained stalled. Something would have to change. Armstrong, in the 1920s, had an enormous personal fortune. During the war years it was disappearing and Armstrong could see that he would soon be unable to keep up his research and payroll as well as having to pay his never-ending legal bills. When he had no other choice, Armstrong reluctantly billed the government for some of his work on the FM radar effort. In a speech given in 1974, one of Armstrong's former attorneys discussed Armstrong's free license for the military use of the FM patents. In his estimate, due to the amount of equipment that was produced, the royalty fees would have totaled "in the small millions of dollars."[10]

If Armstrong turned his lab over for a full development project, he would have to turn control of the lab over to the agency running the project. This was not the way Armstrong wanted to work. He came up with an alternate plan. He still did not charge for use of his patents or his work on FM communications gear, but rather came up with a plan to charge for research work on the basis of payments billed for specific projects, mostly related to FM radar. With this method of individual contract research projects, he kept control of his laboratory and only had to answer to the government agencies by fulfilling these well-defined projects. The cover page of a final report is shown in Fig. 9.

Before the war years, General Roger B. Colton, director of the Signal Corps Laboratories saw the poor state of the outdated communication equipment that would have to serve the army if the war in Europe should involve the United States. He understood the benefits FM communication equipment could provide, and he consulted with Armstrong. The head of the Signal Corps Research and Development Department was Colonel Louis B. Bender, who would be responsible to make a design that could be sent to suppliers. Bender was not in favor of FM and he had commented that RCA had serious concerns about FM and perhaps that made him want to stay with the old AM technology. Armstrong gave demonstrations using equipment similar to F. M. Link's 2-way radios that were installed for the Connecticut State Police. Then Armstrong took it on himself to have Radio Engineering Laboratories (REL) build 28 mobile FM radio sets for the First Army to try during summer maneuvers in 1940. The trial was a great success and with the pressure of General Colton and others, Colonel Bender agreed to develop FM communications.[11] Arrangements were made with Armstrong to assist in the development of these devices in 1941. The task of designing, developing and testing the ground communication equipment was carried on at Camp Evans at Fort Monmouth, NJ. The equipment was predominately manufactured by Western Electric as well as Motorola and F. M. Link.[12] Transmitters and receivers would

have to be reliable and easy to operate with little training. They also had to be capable of covering many channels. Some models had 80 channels that may need to be changed at the flip of a switch. It was decided that this could only be accomplished with crystal-controlled oscillators. As this type of circuit design was relatively new at the time, the production of crystals in these quantities was not available. As happens in time of war, hundreds of small companies were given the training and contracts to answer the need for crystals (Fig. 10, Table 3).



Final Report

Contract W28-099-ac14

HIGH POWER FREQUENCY MODULATION DOPPLER RADAR SYSTEM

Prepared by

Robert E. Hull

Robert E. Hull
Project Engineer

Approved by

Edwin H. Armstrong

Edwin H. Armstrong

ARMSTRONG LABORATORY,

Alpine, New Jersey

Fig. 9. Reports like this were conducted on a contract basis for the war effort. (Armstrong Archive, Columbia University Library)

Radio Set SCR-509 and SCR-510 / BC-620-A
Year 1942

Radio Set SCR-509 and SCR-510 contain a portable, low power, frequency modulated Radio Receiver and Transmitter BC-620, communication over a range of approximately 5 miles. The set may be operated from a stationary position, such as on the ground or on some other stationary support. It obtains its power from dry batteries. Radio set SCR-510 may also be used in veichular installations, obtaining power from the veichular battery. Radio set SCR-510 contain additional components necessary when used in vehicular service.

Freq. range.:	20 - 27.9 MHz using 80 channels (cristals)
IF:	2.88 MHz
Mode:	FM Voice
Tubes:	4 x 1LN5 1 x 1LC6 1 x 1LH4 2 x 3B7 4 x 3D6 1 x 1294
Pwr. output:	2 W
Pwr. supply:	6 - 12 - 24 Volts Veichular Operation BA-39 and BA-40 Batteries Portable Operation
Weight:	15 Kg

Fig. 10. FM ground communications gear like the SCR 509 & SCR 510 shown here helped win the war. This was a low-power portable set with a range of approximately five miles. (www.radiomilitari.com/bc620.html)

Table 3. FM equipment of World War II U.S. ground forces. (Author)

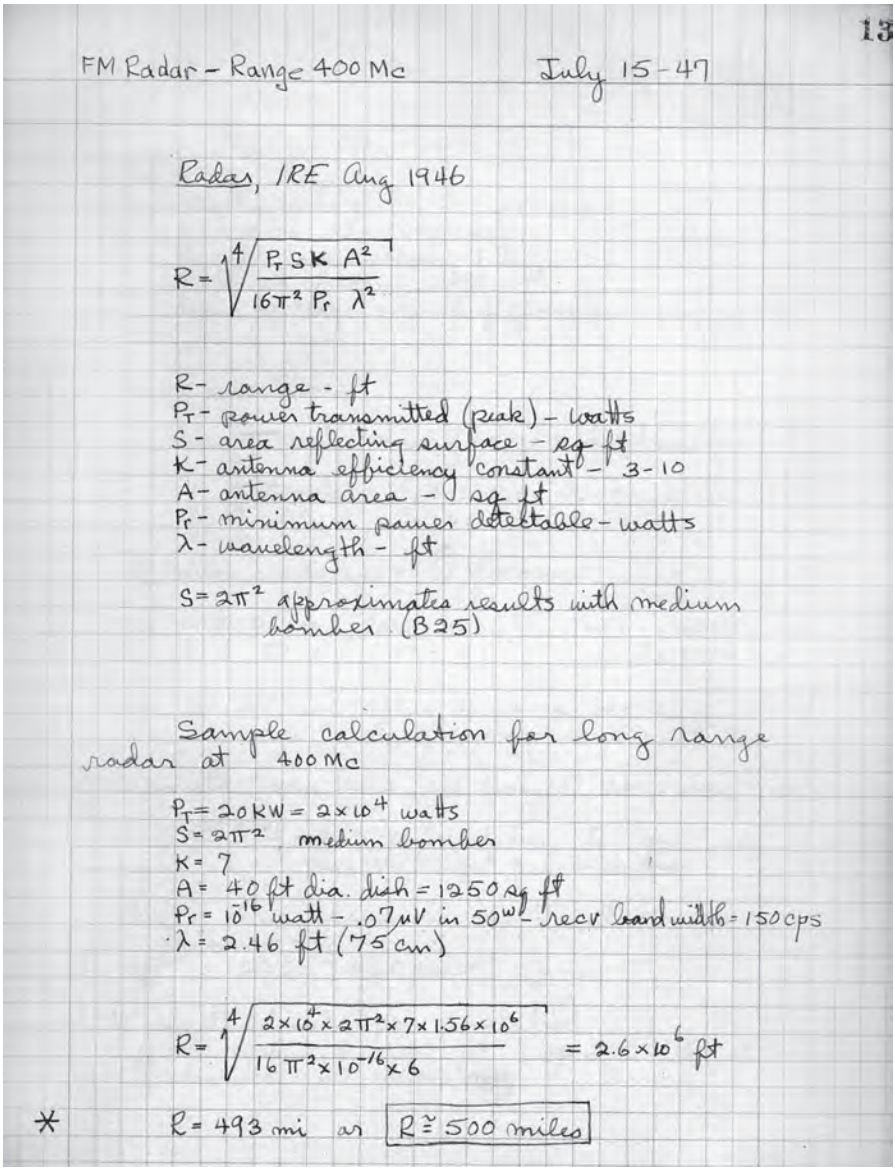
SCR 608	Truck mounted for artillery use
SCR 508	Truck mounted for armored force use
SCR 509, SCR 510	Portable low power receiver and transmitter
SCR 299, SCR 399	Long range truck mounted
SCR 300	Walkie-Talkies (back pack)
SCR 536	Handie-Talkies

Before the FM ground communications became available, the standard military practice was to use AM communications for a short distance; then signal corpsmen would run wire lines to the front lines and AM transmission would be used as the army advanced. FM transmission allowed for a better plan. Trucks were outfitted with FM relay transmitters and would be placed at about 30 mile intervals. This allowed the armored divisions to advance at a rapid pace. General George Patton's Third Army took full advantage of FM relays as they rapidly advanced across France and into Germany. The navy also made use of FM for short-range communications. Military historians often credit the use of FM relays as one of the top five technical developments that helped win the war.

Also, at Camp Evans, an FM radar installation, using an SCR-271 antenna, was assembled for testing (Fig.11). The

Fig. 11. The FM radar test site at Camp Evans, near Belmar, NJ, showing the antenna and radio shack. (Armstrong Archive, Columbia University Library)

system did have both positive results and some drawbacks. None of this work had any applications during the war years. The final report for one of the radar projects was submitted by Hull in 1947 (Fig. 12). Compared to the AM pulse radar then in use, FM radar had a relative slowness, but also in comparison to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FM Radar – Range 400 Mc
July 15-47
Radar, IRE Aug 1946
$R = \sqrt[4]{\frac{P_T S K A^2}{16\pi^2 P_r \lambda^2}}$
R- range - ft
P_T- power transmitted (peak) – watts
S- area reflecting surface – sq ft
K- antenna efficiency constant – 3-10
A- antenna area – sq ft
P_r- minimum power detectable – watts
λ- wavelength - ft
$S = 2\pi^2$ approximates results with medium bomber (B25)
Sample calculation for long range radar at 400 Mc
$P_T = 20 KW = 2 \times 10^4$ watts
$S = 2\pi^2$ medium bomber
K = 7
A = 40 ft dia. dish = 1250 sq ft
$P_r = 10^{-16}$ watt – .07 μV in 50Ω – recv bandwidth = 150 cps
λ = 2.46 ft (75 cm)
$R = \sqrt[4]{\frac{2\times10^4 \times 2\pi^2 \times 7 \times 1.56 \times 10^6}{16\pi^2 \times 10^{-16} \times 6}} = 2.6 \times 10^6$ ft
R = 493 mi or R ≅ 500 miles

Fig. 12. Notebook entry showing the basic radar range equation and calculations of the 400 MHz FM 20 kW radar range as approximately 500 miles. (Armstrong Archive, Columbia University Library)

AM radar, the report appears to show that it had a much longer range. The example in the report shows detection of a bomber at 500 miles. Research on FM radar would continue by others well past the war years. Armstrong's work may well be one of the stepping-stones leading to the long-range defense systems that protected the United States during the cold war years and beyond.

When the need for the equipment that Armstrong built for the Camp Evans testing had ended, it was repurposed for another long-range radar experiment. Under the direction of Lt. Colonel John H. DeWitt and Chief Scientist E. King Stodola, the equipment was modified to point the radar antenna at a distant target. The Project Diana "moon bounce" experiment was to do just that, bounce a radar pulse off the moon and receive the reflection. It worked; the pulse was sent and was received back. The range calculation placed the moon 238,000 miles away. Because it was so well made, the Armstrong equipment was modified to use pulsed AM instead of continuous wave FM. Therefore, Armstrong did not want his name associated with the project. In an interview, former Alpine employee, Renville McMann Jr. recalled asking Armstrong if they could duplicate the project at Alpine. Armstrong gave a quick response, "Reny we're not doing that here. Don't aim that thing at the moon. Don't let me catch you doin' it."[13] Certainly, Armstrong's name alone would be enough for the press and public to give him credit for something that was not his work. That was not his way.

Competition with Television

The story of the development of television fills its own history books. However, it relates to the history of FM in many aspects. To add pictures to radios was an inventor's dream and it was making tediously slow progress beginning with the mechanical devices of the 1920s. To the public, the reports were that television was just around the corner. In 1933, when Sarnoff attended Armstrong's FM demonstration, RCA had already invested large sums into TV research. Field testing from the Empire State Building was completed using a system with a mechanical camera and an early kinescope (CRT) receiver. The iconoscope camera tube was in late development and its introduction would complete an all-electronic television system. During the depression, Sarnoff was taking a huge risk that TV could successfully go commercial. Everything Sarnoff was shown about FM was seen through his television lens—a lens that viewed how FM could impact his television plans. The record is very consistent. The records show that in public statements and testimony before the FCC, he was all consumed by television. In speaking to the FCC regarding frequency allocations, Sarnoff fought for television channels. To Armstrong's dismay, Sarnoff's testimony did not even mention FM broadcasting. From this behavior, it is not difficult to see Sarnoff as the man behind the curtain, manipulating the industry he controlled, to keep FM at bay and clearing the path for television. When some of these events and actions that impacted FM seem implausible, viewing Sarnoff's

actions through his television lens helps explain his motivation.

FM did have one curious victory over Sarnoff and the television proponents. After the 1939 World's Fair introduction of television, the FCC still needed to give final approval before commercial television could go on the air. With all of the fight RCA waged against FM, how did the television standards that took us from the 1940s all the way to high-definition TV, end up with FM audio? The story begins with a discussion between David Sarnoff and James Lawrence Fly, commissioner of the FCC. This discussion occurred in early 1940 as Sarnoff laid out his plan for commercial television to begin on September 1, 1940.[14] Believing that he and the commissioner were in agreement on the current TV standards, and wanting to get the most publicity possible, Sarnoff moved ahead. On March 20, 1940 Sarnoff went public with newspaper ads saying that TV was arriving. Chairman Fly felt deceived, he did not see the discussion as signaling his approval of the television standards. He also went public, claiming that this situation was an attempt by Sarnoff to create a television monopoly by selling TVs built to the transmission standards that RCA favored. That would make it difficult for the FCC to change the standards once the public was buying televisions. Fly told the public that he was the one fighting the giant corporation to protect the little guy. This caused a stalemate and approval was delayed, which placed Sarnoff in a difficult position. Television buyers would want to be confident that their TV would not become obsolete. It was costing RCA money to have commercial television delayed. At one point, President Roosevelt attempted to bring the two men together, but his effort was to no avail.

At that time in 1940, the television standards being tested were those proposed to the FCC by the RMA (Radio Manufacturers Association). To settle the standards issue, the NTSC (National Television Standards Committee) was created. The format they developed, simply referred to as NTSC, became the official standard until high-definition TV. The most important differences included changing the horizontal resolution from 441 lines to 525, and to the surprise of many, changing the audio portion of the TV signal from an AM subcarrier to an FM subcarrier.[15]

Also, to the surprise of many, there was no strong protest from David Sarnoff. By accepting this standard, was he admitting that FM would be the audio format of the future? More likely, two possibilities seem to have kept Sarnoff from protesting. The delays up to this point had already been too costly. Causing the standards to change again would have caused more hearings and findings by more committees. Another delay was intolerable. Another factor may be one only known to David Sarnoff. At the time, RCA had plans for its own FM radio circuits and he planned use them to circumvent Armstrong's patents. Why fight the FM regulation, when he had no plans to pay Armstrong any royalties for the use of FM in televisions. When the war ended, television was no longer

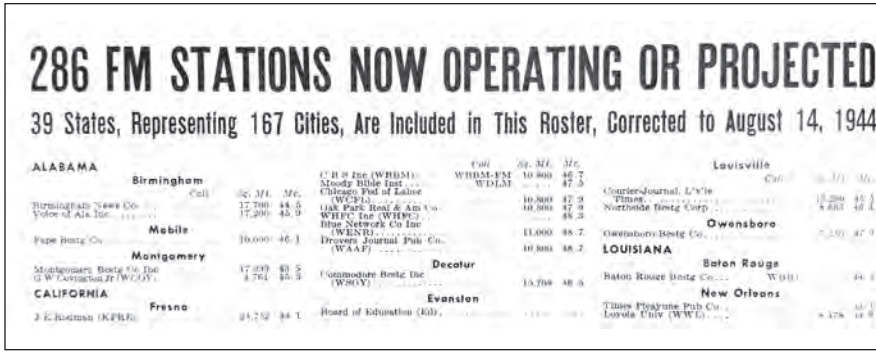
just around the corner. Although used in millions of television receivers during the 1940s, no royalties were paid to Armstrong. More than a decade later these infringements would be listed in the demands for damages in Armstrong's lawsuits.

The Battle of Regulation

Broadcast Frequency Change

The attacks on FM by Federal Communications Commission regulations could not have occurred without the major players in the broadcast industry taking advantage of flaws in the FCC. From the beginning of the FCC, it was obvious that a revolving door of personnel existed between the FCC and those corporations they were intended to regulate. In the areas of engineers, experts and policy makers, their positions between working for the FCC and working for a corporation like RCA, would flip back and forth on a regular basis. As a result, hearings could be held, voices could be heard from both sides, and a policy decision would come down on the side of the big corporations. Efforts were made over time to correct this situation, sometimes with positive results for a time, but the same problems in Armstrong's time are still problems today.

In 1943 as U.S. businesses started to plan for a post-war America, the FCC started to plan the best use of the radio spectrum. Advisory panels were formed on different parts of the radio business. As the number of FM stations was growing (Fig. 13), there was a panel studying the expected use of FM in years to come. Each of Radio Technical Planning Board (RTPB) panels would consist of experts in their field from government or the radio business. RTPB 5 was to study the FM situation. At the hearings, Armstrong, many FM proponents like Paul DeMars, engineer for The Yankee Network, and the reports from RTPB 5[16] and RTPB 2, all spoke up for FM to remain in the 42–50 MHz band with some additional space allotted for more channels. At this point there were 500 stations on the air and about 500,000 receivers in use. All reports were that the FM service was exemplary in this band. Armstrong funded research to disprove



286 FM STATIONS NOW OPERATING OR PROJECTED

39 States, Representing 167 Cities, Are Included in This Roster, Corrected to August 14, 1944

ALABAMA

Birmingham

Mobile

Montgomery

CALIFORNIA

Fresno

Louisville

Owensboro

LOUISIANA

Baton Rouge

New Orleans

Fig. 13. Advertisement showing 286 FM stations "on the air" as radio prepares for the post-war period. (*FM Magazine*, Aug. 1944, p. 16)

the line-of-sight arguments often leveled against FM, claiming limited range past sight of the tower. His engineers took equipment as far as Louisiana and under good conditions, picked up the Alpine, NJ broadcasts. Even RCA spoke up, at least in public, saying FM should be left in its place.

Then an unexpected voice entered the discussion. A former military communications expert, now working for the FCC, Kenneth Norton, produced a report. He advised the FCC, stating that the nine-year cycle of sunspot activity was about to enter a more active period. He concluded that this would cause interference in the FM band for between 800 and 2000 hours per year. It was proposed that FM be moved from the 42–50 MHz band to the 88–108 MHz band that we know today. Armstrong charged that this would deal a death blow to FM. This would not be a matter of just changing the dial settings. Equipment would have to be designed and built to operate at the higher frequency. All of the broadcast transmitters and the half million receivers in listeners homes would be instantly obsolete and unusable.

Armstrong and the FM proponents saw flaws in this prediction and called for another opinion, this time from the National Bureau of Standards, which had expertise in this area. They testified that the sunspot interference concern at the current FM frequency was unwarranted, that there was no need to move FM.[17]

It was then announced that the FCC was going to collect more data on this issue from the military. This would be done behind closed doors in secret testimony on March 12 and 13, 1945. After that occurred, the FCC announced that the FM band would have to be switched to 88–108 MHz in June 1945. Of course, Armstrong and his FM supporters were stunned. FM would have to move. Years later during some congressional testimony, the truth would come out. The testimony agreed that the sunspot prediction was wrong and the FCC report was changed to say the sunspots were still the reason for the FM band to be changed. The 42–50 MHz band was given to television for channel 1. No mention was made that the predicted interference would be much worse for the AM television video signal. In the end no sunspot interference occurred.

A few years later, at an FCC hearing, Armstrong had the opportunity to question Kenneth Norton on his errant sunspot interference prediction. He told Norton directly, "You were wrong." Norton replied: "Oh certainly, I think that can happen frequently to people who can make predictions on the basis of partial information. It happens every day." After all of the impact that prediction had on the FM business, all that was left for Armstrong was to make a statement to the commission: "That is the point I would like to make, Mr. Chairman, the type of engineering advice this commission had been given, and it has resulted in chaos to those of us who have been trying to do an engineering job."[18]

Not only did the FM listener now have a radio that would not receive anything, the FM broadcasters and manufacturers had to convince the public that

this just wouldn't happen again. The Zenith Radio Corporation, Chicago, IL, under their president E. F. McDonald, was an early FM proponent and FM licensee.[19] To have programming to attract buyers for their FM radios, Zenith built its own FM radio station. The first FM radio station in the Midwest, station W9XEN, started broadcasting under an experimental license on February 2, 1940. Later when approved for commercial broadcasting as W51C, the transmitter was moved to the Field Building on the Chicago Loop. When power was increased to 50,000 watts, their signal covered the middle of the country. The station call sign was changed to WEFM (for E. F. McDonald) and for a time it was the most powerful FM station in the country.[20]

The decision to move FM to the higher frequency band had a huge impact on Zenith. Their broadcast station and all of the receivers bought by loyal Zenith customers would go silent. Objections brought to the FCC by Zenith and other manufacturers fell on deaf ears. What could Zenith build and sell to radio buyers? Should they still build radios on the old band in hopes that the decision would be reversed? Should they tool up and build their products to the new band before the actual transition and before their station could be rebuilt? Against the recommendation of the FCC,[21] who wanted to "protect" the public from two band radios, Zenith built their own transition product, an AM-FM receiver with 2 FM bands, 42–50 MHz and 88–108 MHz. The FCC went as far as to make threats that if manufacturers kept producing FM receivers on the old band, they would shut down all FM broadcasting.[22] At this time, just after the war, Zenith was selling 36 percent of all the FM radios produced in the country; no wonder, look at the beauties in Fig. 14 and Fig. 15

Fig. 14. Zenith model 8-H-023 AM and FM (old band) and FM (new band), 1946. (Author's Collection)

Fig. 15. Zenith model 7-H-820 AM and FM (old band) and FM (new band), 1948. (Author's Collection)

with their sweeping dial. They continued broadcasting on the old band until the last possible day. During this time Armstrong proposed to the FCC that both FM bands continue to operate, keeping high powered stations like Zenith's in the old band. This request was denied (Table 4).

Table 4. Final allocations, 42–108 MHz. (Author))

Use	Frequencies
FM	
Noncommercial educational	88–92 MHz
Commercial	92–100 MHz
Interim allocation for existing transmitters pending transition	42–44 MHz
FACSIMILE	
All (facsimile eventually to move upwards, leaving 106–108 MHz for FM)	106–108 MHz
TELEVISION	
channel 1	44–50 MHz
channels 2–4	54–72 MHz
channels 5–6	76–88 MHz
NON-GOVERNMENT	
Fixed & mobile services	42–44 MHz
(when FM moves up)	72–76 MHz

The Single Market Plan

RCA was not the only corporation to use its power to delay or cripple the advancement of FM. The Columbia Broadcasting System, CBS, was the other big power in broadcasting in the 1940s. The corporation had an obvious motive—to protect the status quo in AM broadcasting. It was clear at the time that broadcasting was a de facto monopoly. The lack of open spaces on the broadcast band kept competition down. The opportunity for market share that new independent FM broadcasters could take away was viewed by AM broadcasters as a mortal threat. If FM could be diminished and delayed over a long period of time, the big corporations could work their way in and keep their control of broadcasting. The CBS efforts were in the area of proposed regulations and their leader in these efforts was executive vice president Paul Kesten. He became recognized for his smooth manner of making proposals that he could explain were for the good of FM until one looked a little deeper into the consequences of the proposal. In the pro-FM press, he earned the nickname Plausible Paul.[23]

In 1944 Paul Kesten made a proposal to the FCC that he said would help expand the number of stations around the country. He reasoned that since FM transmitters had greater coverage for the same amount of power, then why not regulate the amount of power authorized for a station so that it could only cover the immediate market served by the station. In comparison, AM stations may be licensed to cover just a small single market or a larger regional market or in some cases a clear channel station that could have unlimited coverage. The amount of coverage a station has also directly affects the advertising dollars a station can generate. This change, which he stated was to "help FM", was called "The Single Market Plan." Kesten pointed out that a problem that evolved with AM broadcasting was the hierarchy of different size stations. He stated that FM should be more democratic than AM, allowing many broadcasters in small markets. Although this may at first sound plausible, it would have some serious implications for independent FM broadcasters.

His proposal wasn't only for new stations but would require that current stations reduce power to match their location. For example, Armstrong's W2XMN station would have to reduce their transmitter power from 40,000 watts to 1,200 watts. The Zenith station that served the entire Midwest would be reduced to the Chicago area. This power reduction would reduce the ability to relay programs between stations. Critics were quick to note that Kesten did not propose that these rules also be applied to AM radio and it also appeared that the real motive was to prevent high power FM stations from competing with the AM Clear Channel Stations. These AM stations were the big money stations of the big money corporations. Although many of the problems this regulation would cause for the FM broadcasters were pointed out at FCC hearings, the new regulation was enacted.

Duplicate Programming

By June 1945 Plausible Paul Kesten was trying to "help FM" once again. Kesten reasoned that it would help FM if there were more hours of programming provided on FM, then more people would buy FM radios. Therefore, if the broadcasters, which also had AM stations, were permitted to simply duplicate the AM programming on their FM transmitters, the increased programming would increase interest in FM. Again, this would have negative implications for many independent FM broadcasters and again the FCC adopted the regulation.

The AM-FM stations saw an immediate reduction in programming costs, as all they did to supply FM was throw a switch. The immediate result this regulation had was to lower the cost of FM broadcasting for the big AM-FM stations but not for the small independent stations. This allowed the AM-FM stations to lower their charges for FM advertising, in most cases down to zero. If an advertiser buys time on AM, the FM time was included at no charge.

In an article published in *Broadcasting*, January 17, 1944, RCA's broadcast network the National Broadcasting Company announced its new policy intended to stimulate the growth of FM broadcasting. The new policy included a change in the charges to network affiliates. There would be no extra charge to them, if programming broadcast from the network's AM service is duplicated on their FM service. They stated that this increased FM programming would boost public interest in FM. They also changed their published rates for advertisers on FM. There would be no additional charge for adding FM broadcasting to their AM advertising cost. The concept promoted to advertisers was that of a single charge for a single service.[24]

This again was the same approach of stating a change as being "for the good of FM" until one looks at the results this policy change will have on the independent FM broadcasters, in particular FM stations with no AM affiliate. How can the independent FM station sell advertising when the station just down the dial is giving it away? This had a dramatic effect on the finances of the independent station. They were forced to find a niche of programming that could attract some listeners at the lowest possible cost and find potential advertisers that have an interest in attracting these listeners.

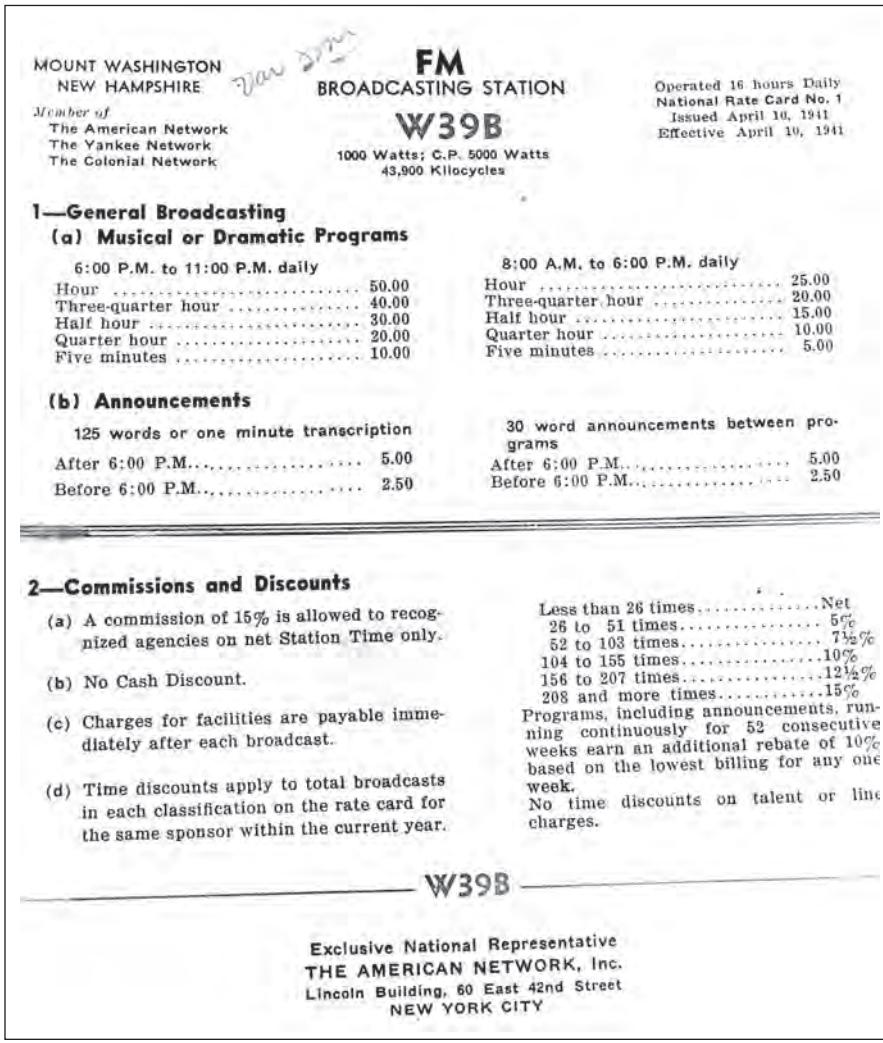
Increased Programming Hours

Since AM-FM stations had increased their programming hours, perhaps it would be a good idea to require independent FM stations to increase their programming hours. Perhaps this would also be "good for FM." At the time FM stations were required to broadcast six hours per day. The new regulation would require that after two years on the air, stations would be required to provide 12 hours of programming per day. The earlier regulations had already put a financial strain on the new stations. The additional hours would add programming time that had little appeal to advertisers. The cost of adding programming, with little or no increase in revenue, was yet another burden placed on the independent FM stations.[25] The

advertising rate card of Fig. 16 shows how little income was being generated by FM programming.

At yet another hearing before the FCC, proponents of FM and Armstrong spoke out about this additional regulation of FM. Armstrong suggested to the FCC that perhaps they should form another committee, this time "if only to determine whether the medicine which the Commission is proposing to administer to FM broadcasting will not kill rather than cure the patient."[26]

Another delay to the growth of FM came from the FCC answering complaints that too many small independent



MOUNT WASHINGTON
NEW HAMPSHIRE

Member of
The American Network
The Yankee Network
The Colonial Network

FM
BROADCASTING STATION
W39B
1000 Watts; C.P. 5000 Watts
43,900 Kilocycles

Operated 16 hours Daily
National Rate Card No. 1
Issued April 10, 1941
Effective April 10, 1941

1—General Broadcasting

(a) Musical or Dramatic Programs

6:00 P.M. to 11:00 P.M. daily

Hour	50.00
Three-quarter hour	40.00
Half hour	30.00
Quarter hour	20.00
Five minutes	10.00

8:00 A.M. to 6:00 P.M. daily

Hour	25.00
Three-quarter hour	20.00
Half hour	15.00
Quarter hour	10.00
Five minutes	5.00

(b) Announcements

125 words or one minute transcription

After 6:00 P.M.	5.00
Before 6:00 P.M.	2.50

30 word announcements between programs

After 6:00 P.M.	5.00
Before 6:00 P.M.	2.50

2—Commissions and Discounts

(a) A commission of 15% is allowed to recognized agencies on net Station Time only.

(b) No Cash Discount.

(c) Charges for facilities are payable immediately after each broadcast.

(d) Time discounts apply to total broadcasts in each classification on the rate card for the same sponsor within the current year.

Less than 26 times	Net
26 to 51 times	5%
52 to 103 times	7½%
104 to 155 times	10%
156 to 207 times	12½%
208 and more times	15%

Programs, including announcements, running continuously for 52 consecutive weeks earn an additional rebate of 10% based on the lowest billing for any one week.

No time discounts on talent or line charges.

W39B

Exclusive National Representative
THE AMERICAN NETWORK, Inc.
Lincoln Building, 60 East 42nd Street
NEW YORK CITY

Fig. 16. Rate card of 1941 showing fees charged to FM advertisers by station W39B, Mount Washington, NH. (Poppele Collection FM Scrapbooks, AWA Museum)

stations were owned by the local newspapers. Claims were made that the public would be better served by hearing from more than one voice in their community. However, this had the effect of temporarily slowing the processing of new licenses to nearly a halt as license ownerships were investigated.[27]

The Battle of Patents

Author Gleason Archer wrote about the radio business in the 1920s and 1930s. In his 1939 book he writes little about FM. However, he does make the point that frequency modulation is the use of a natural characteristic of radio waves. He notes that after years of dedicated research and at great expense, Armstrong developed a method of utilizing this natural characteristic to improve the transmission and reception of radio signals.[28]

That being understood, one could argue that as different as FM radio may be, a clever inventor can devise another method of converting the transmitted FM signals into audio waves, without the use of the method employed in Armstrong's patent. That is exactly what RCA attempted to do. From the time the Empire State field testing ended and Armstrong went to develop FM on his own, RCA increased its own research. Many patent applications were prepared or filed during this period. From a business and legal standpoint, this is a smart action for RCA to take. If legal challenges are anticipated, RCA would stand on much firmer ground if they could demonstrate they had their own FM system with less or no need for the use of Armstrong's work. During the 1930s and 1940s, RCA maintained a continuous program of FM research.

In the 1940s there were a number of patents filed for improved FM detectors and ratio detectors. Some were assigned to RCA, including some by prominent engineers already experienced in FM design (Table 5).

The patent, RCA stated, that was the basis to build their FM receivers was a ratio detector as proposed by Seeley. In a paper delivered before the New York section of the Institute of Radio Engineers on October 3, 1945, by Stuart W. Seeley, manager of the Industry Service Division of RCA Laboratories, it was described as an innovation in that it did not need a limiter stage. A description of the circuit was also printed in the October 1945 issue of *Radio* magazine.[29]

RCA's motivation to build a strong patent position in FM without the need for an Armstrong license was more than the financial one that could occur in a legal contest with Armstrong. A major component of RCA's business model was built around the licensing of their patent portfolio to all major manufacturers in the radio business. The licensees could see the public's interest in FM building. Some license holders, following the lead of GE and Zenith, had taken an Armstrong license in addition to their RCA license. Others looked only to RCA for license to produce FM receivers. As the legal issues would not be settled for some time, many manufacturers took the chance and produced radios under RCA's claim that the ratio detector was a new FM detector.

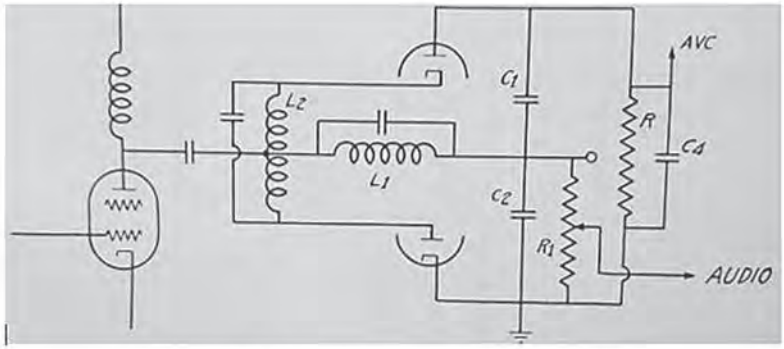
Table 5. Early patents for FM detector circuits. (Author)

U.S. patent number	Date	Inventor	Assigned to	Description
2,121,103	June 21, 1938	Stuart W Seeley	RCA	Frequency variation response circuits
2,256,078	July 31, 1940	Murray G. Crosby	RCA	FM detector
2,422,083	Mar. 20, 1942	Murray G. Crosby	RCA	FM detector
2,429,762	Feb. 5, 1944	W. R. Koch	RCA	Combined FM-AM detector
2,550,510	June 3, 1949	James F. Wilcox	GE	FM detector circuit
2,561,149	July 17, 1951	Saul Solomon	RCA	FM detector circuit
2,572,424	Oct. 23, 1951	Bernard Amos	DuMont Laboratory	FM ratio detector
2,653,230	Sept. 22, 1953	Robert C. Moses	Sylvania	Ratio detector

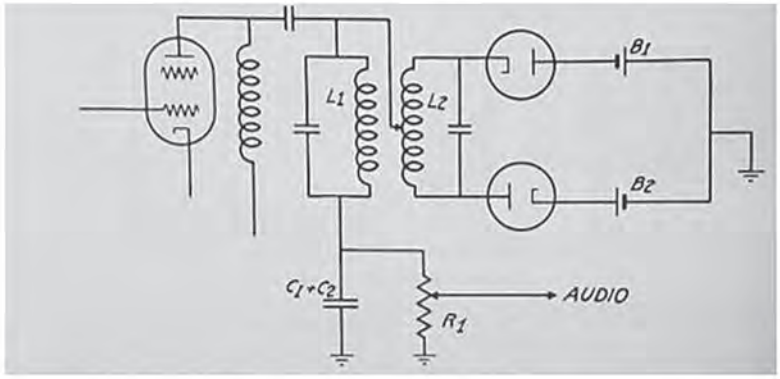
Howard Armstrong published a response to RCA's claims regarding the ratio detector. "A Study of the Operating Characteristic of the Ratio Detector and its Place in Radio History" was published in the 1948 *Proceedings of the Radio Club of America*. He begins with a historical look at earlier work of Armstrong's, the regenerative circuit in particular, and how others twisted the invention around to claim it to be the work of others. His feelings are best told in Armstrong's own words:

> "General realization of the commercial value of FM was delayed for many years. But when its commercial value became apparent to everyone, history repeated itself and the modern counterpart of the ultraudion (De Forest's claim of the regenerative circuit) appeared on the scene in the form of the ratio detector. Let us now examine this seemingly technical innovation."[30]

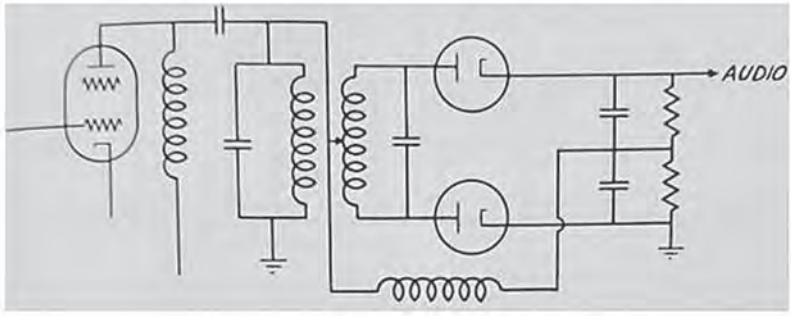
He explains that the claims that the "ratio detector" was an innovation and improvement in detecting an FM signal and was able to perform without a limiter stage that Armstrong's discriminator needed. The article shows a diagram of the ratio detector as drawn in the RCA literature, upper part of Fig. 17.



RCA Ratio FM Detector as published by RCA



RCA Ratio FM Detector as redrawn by Armstrong



Compared to Armstrong Discriminator detector

Fig. 17. Armstrong's analysis of RCA's ratio detector. At the top is shown the RCA ratio FM detector circuit as published by RCA. In the middle is the RCA ratio detector circuit as redrawn by Armstrong. At bottom is the Armstrong discriminator detector circuit for comparison. (Compiled from Edwin H. Armstrong, "A Study of the Operating Characteristics of the Ratio Detector and it's Place in History," *Proceedings of the Radio Club of America*, 1948, Vol. 25, No. 3)

Armstrong charges that the method of drawing the diagram and the published explanation of the circuit's operation was "obscure and unconventional." He then continues systematically and redraws the diagram, finally arriving at a drawing very close to the drawing of Armstrong's discriminator circuit, as in the middle and lower part of Fig. 17.

Armstrong goes on to explain that the ratio detector, contrary to the RCA description, does also function as a limiter. The results are shown that the circuit's function as a limiter is inferior to the Armstrong version, which has a separate tube circuit as a limiter. His reason for pointing out the limiter function as well as the similarities in the circuitry is to contest the claim by RCA that the ratio detector is a new method of detecting the FM signal.

From his analysis, Armstrong's conclusion was that the ratio detector was not an innovation but rather an inferior performing infringement of his discriminator patent. No response came from RCA. As the advertisements and promotional materials for the RCA sets were released, the ad men categorized the new sets as employing RCA's "Super FM." RCA also tried to strengthen their legal standing by filing infringement claims against Armstrong's patents. These charges would later be added to Armstrong's list of harassments perpetrated by RCA.[31]

As there was demand for combination AM-FM receivers, there was demand for a low-cost detector circuit that would detect both AM and FM. One designed and produced by others that used a 6S8 tube,[32] that was described in the RCA Receiving Tube Manual, used a triple diode and single high mu triode. The manual shows the design intended for an AM detector, FM detector and audio amplifier. In the Farnsworth model GK-085 circuit using the 6S8, the single tube also performed the function of FM AVC (Fig. 18).

Another detector circuit was introduced by Philco using a unique new tube manufactured by Sylvania-Hygrade, the FM1000 tube (Fig. 19). The construction is a heptode seven-element tube for use as a FM detector used in a circuit called a locked-in oscillator detector circuit.[33] This circuit is used in the Philco 48-482 AM-FM table radio, introduced in 1948 (Fig. 20). The operation is described in *Riders Vol XVIII How It Works*. In a very simplified explanation, one stage of the FM1000 is used as an oscillator. A second circuit is locked to the final IF stage output, with the IF stage peaked at 10.7 MHz. As the incoming modulated signal varies higher and lower in frequency, the change is fed back through the FM1000 tube to also change the frequency of the oscillator. The changes are converted to a change in DC voltage proportional to the frequency changes thus producing the audio signal. This circuit could be described as an early vacuum tube version of a phase locked loop as used in modern day receivers.

Other variations of FM detector circuits were introduced by unlicensed manufacturers. All would defend their actions claiming protection under RCA's license or claim that they had invented a method separate from Armstrong's to

detect the FM signal. It would be hard to determine whether Armstrong saw the most damage caused by the financial aspect of the patent violators or the damage to the reputation of FM caused by the manufacturing of inferior radios. Armstrong published an open letter to the radio buyers warning them of the danger of buying an inferior radio built by one of the patent violators. A list of the authorized license holders was printed on the final page (Fig. 21).

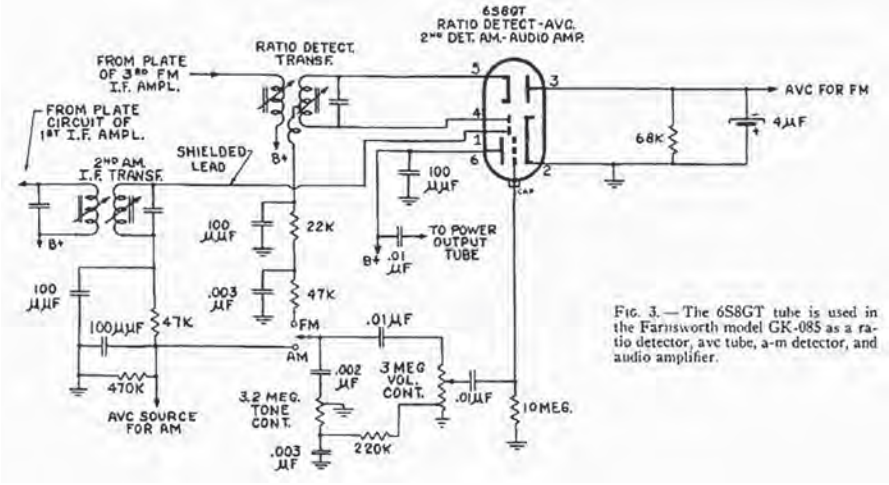


FIG. 3.—The 6S8GT tube is used in the Farnsworth model GK-085 as a ratio detector, avc tube, a-m detector, and audio amplifier.

Fig. 18. A combination AM-FM detector using a 6S8GT vacuum tube is used in the Farnsworth model GK-085 as a ratio detector, AVC tube, AM detector, and audio amplifier. (*Riders Vol. XVIII How it Works*, John F. Rider Publishers Inc., p. 3)

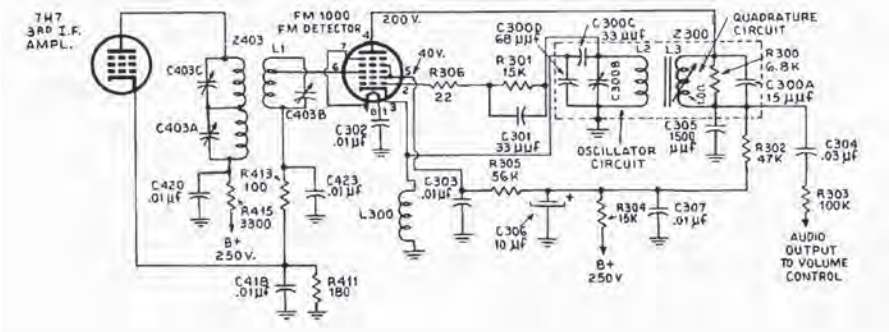
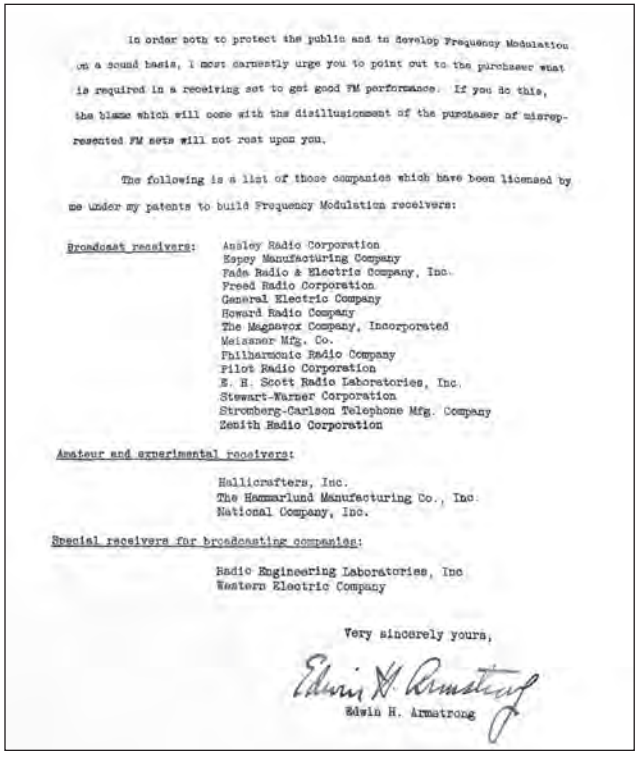


Fig. 19. Philco Corporation FM detector using the FM1000 tube. The locked-in oscillator detector circuit is used in the Philco model 48-482. The FM1000 tube used in this circuit is a special Pentagrid tube. (*Riders Vol. XVIII How it Works*, John F. Rider Publishers Inc., p. 5)

Fig. 20. Philco model 48-482 AM-FM radio, not licensed by Armstrong. (Author's Collection)



In order both to protect the public and to develop Frequency Modulation on a sound basis, I most earnestly urge you to point out to the purchaser what is required in a receiving set to get good FM performance. If you do this, the blame which will come with the disillusionment of the purchaser of misrepresented FM sets will not rest upon you.

The following is a list of those companies which have been licensed by me under my patents to build Frequency Modulation receivers:

Broadcast receivers:
Ansley Radio Corporation
Espey Manufacturing Company
Fada Radio & Electric Company, Inc.
Freed Radio Corporation
General Electric Company
Howard Radio Company
The Magnavox Company, Incorporated
Meissner Mfg. Co.
Philharmonic Radio Company
Pilot Radio Corporation
E. H. Scott Radio Laboratories, Inc.
Stewart-Warner Corporation
Stromberg-Carlson Telephone Mfg. Company
Zenith Radio Corporation

Amateur and experimental receivers:
Hallicrafters, Inc.
The Hammarlund Manufacturing Co., Inc.
National Company, Inc.

Special receivers for broadcasting companies:
Radio Engineering Laboratories, Inc
Western Electric Company

Very sincerely yours,

Edwin H. Armstrong

Fig. 21. Last page of Armstrong letter to the radio public advising which companies produce quality licensed FM radios. (Poppele Collection FM Scrapbooks, AWA Museum)

The Battle of Litigation

The number of patents for various detector circuits led to a number of FM radios being produced by companies without a license from Armstrong. RCA was marketing radios using the ratio detector under the Seeley patent. Although Armstrong saw this circuit as inferior and still an infringement on his patents, RCA saw fit to promote their radios as "Super FM." Also, a number of manufacturers with RCA licenses were introducing FM radios with other detector circuits; the biggest were RCA, Philco, Motorola, Admiral, and Emerson. They would claim protection under their RCA licenses. In addition, Armstrong had to be concerned with the financial burden this competition placed on his loyal license holders. Any company in the 1940s, producing radios in any quantity, would have to take an RCA license to be protected from infringement lawsuits. Armstrong license holders had to have his license plus an RCA license. These manufacturers had to find a way to make a profit while paying fees to both companies while the infringing companies did not.

Attorneys and advisors suggested to Armstrong that he lower the royalty fee from the two percent being paid at the time. They reasoned that a lower fee would encourage some of the violators to become license holders, as the risk of legal fees would outweigh the license fee.[34] They also suggested that he form a corporation to handle the licensing and collection of royalties. Armstrong would not take their advice. In his judgement, reducing the royalty fee would reward the violators and punish the loyal license holders who had been paying the full amount all along. He also refused to form a corporation and delegate the licensing business to others. He wanted to maintain control and not have his decisions questioned. As financial times were hard for his FM license holders, only four of the largest were able to keep up to date on their license fees. General Electric, Westinghouse, Zenith, and Stromberg-Carlson were financially strong enough to keep up payments. While in control, Armstrong was able to decide if he would reduce or delay the fees due from a small license holder if it was producing a good product.

Armstrong was not a stranger to litigation. The battle over the regenerative patent with De Forest had already gone through the full legal process, ending with a Supreme Court decision in favor of De Forest. In May 1934, Armstrong wrote a speech he planned to deliver to a meeting of the Institute of Radio Engineers in Philadelphia. He was planning to return their Medal of Honor awarded to Armstrong for his regenerative circuit. In his mind, if the patent was taken away, he should return the medal. His words expressed his feelings: "It is a long time since I have attended a gathering of the engineering and scientific world, a world in which I am at home, one in which men deal with realities and where truth is, in fact, the goal. For the past ten years I have been an exile from this world and an explorer in another, a world where men substitute words for realities and then talk about the words. Truth in that world seems merely to be the avowed object.

Now I undertook to reconcile the objects of these two worlds and for a time, I believed that that could be accomplished. Perhaps I still believe it—or perhaps it is all a dream…"[35] He never gave that speech because the board members of the Institute of radio engineers had voted to renew their award and would not accept Armstrong's offer to return it. In the world of realities, his colleagues knew who invented the regenerative circuit.

Now, more than a dozen years later, the prospect of litigation and once again fighting in this world of words, must have seemed not like a dream but rather a nightmare. Perhaps he thought he was better prepared for legal battle this time. Having learned many lessons in his earlier patent litigation, Armstrong had confidence that his FM patents stood on a solid footing. They were well written and filed as a group. There was also going to be a process of pre-trial discovery. The purpose of this is for each side to lay out their evidence and to be questioned on their evidence before the case goes to court. With that work done, the courtroom trial period should proceed quickly.

In July 1948, a suit was filed for Edwin H. Armstrong, represented by the law firm Cravath, Swaine, Moore, and Byerly and the law firm Townsend and Watson, both of New York, and attorney William Prickett, Wilmington, DE, in the U.S. District Court in Wilmington, DE, against the Radio Corporation of America, RCA, and its subsidiary, the National Broadcasting Company, NBC. The claims filed in the suit accused RCA of establishing a monopoly in the licensing of radio patents and patent rights and that RCA and NBC "deliberately set out to oppose the growth and development of FM and impair the value thereof by delaying the commercial development and public use of said inventions and to compel the plaintiff to sell and transfer the control of said patents to RCA." He also charged that RCA and NBC issued public statements "belittling and misdescribing" his FM inventions. Armstrong also claims that RCA tried to induce the FCC to allocate to FM "so small a number of usable radio frequencies as to make its development and use on a national basis impossible." It was also charged that RCA instigated "groundless and obstructive interferences in the Patent Office between two of Dr. Armstrong's basic patents and two others owned by RCA." He then claims that RCA and NBC went on to willfully and deliberately infringe upon the plaintiff's said patents and refused to accept a license offered under the same terms as other license holders. He added that RCA insisted on a license based on a lump sum payment and giving RCA the right to sublicense others under such patents. He charged that this would have destroyed the plaintiff's licensing system and would have removed him as a competitor of RCA, "thereby continuing and reinforcing RCA's monopoly of that business."[36]

Armstrong's complaint went on, "RCA, for the purpose of inducing others to infringe upon and disregard said patents, falsely represented to the radio industry that RCA had devised a system of FM broadcasting which did not infringe upon the plaintiff's patents, falsely represented that a radio receiver

which RCA named the "Ratio Detector" did not operate according to the teachings of plaintiff's patents and in other and diverse ways, induced many members of the radio industry to believe that it was safe to infringe plaintiff's said patents, that RCA would protect them from the consequences of such infringement or that they did not require licenses under said patents if they held licenses under RCA patents, thereby causing a large part of the radio industry to infringe upon and disregard plaintiff's patents, all with the deliberate intention of impairing the value of said patents and with the effect of preventing plaintiff from obtaining a fair and reasonable reward for the inventions covered by said patents."[37]

In the article in *Broadcasting* magazine, Armstrong added a personal statement. It concluded with the following paragraph. "Therefore, in protection of my rights and those of my licensees, this suit has been instituted. It will be vigorously prosecuted because RCA's brazen attempt to appropriate my inventions strikes at the very basis of the rights of all inventors and those companies who, under the patent laws of the land, are willing to take the risks involved in bringing worthwhile inventions into public use."[38]

The Battle of Endurance

While there were positive signs for Armstrong and FM as the 1940s began, the 1940s were ending on a negative trend. The pre-trial discovery period seemed never ending. At times the questions put to Armstrong appeared unrelated to the suit but rather for the purpose of adding to the delay of any actual trial. The RCA attorney asked Armstrong why he had license holders place Armstrong tags on the backs of their radios and why were they oval (Fig. 22). The results of the regulations set on the FM broadcasters were taking its toll. FM broadcasters were forced to reduce their coverage area. They were forced to provide broadcasting hours in time periods when they could not sell ads and big AM-FM stations could give away their FM ads. Independent FM broadcasters were losing money and many turned in their licenses. AM-FM stations were duplicating their programming. For these stations, the advertising rates for the FM side was

Fig. 22. Oval tag identifying "The Armstrong FM System" to signify a licensed radio. (Author's Collection)

a throw in. The quality of the FM and AM-FM sets being produced was poor. Testing demonstrated that typical frequency response of these was 200 Hz to 3,000 Hz. The industry made claims that sound quality was not an important issue among radio owners. Other manufacturing industries were booming in the postwar economy but FM was not riding the wave (Table 6, Table 7).

The ultimate endurance challenge for Armstrong would be the never-ending litigation. In the early stages, as friends would ask how the case against RCA was proceeding, he might give a half serious answer that RCA would fight him until "he is dead or broke." The financial situations at FM stations as well as AM stations were declining due to advertising revenues moving to television. By 1953 Armstrong's financial situation was at a low point. Some patents had run out and some license holders could not pay their fees. Other manufacturers declined to pay fees. Armstrong was maintaining his payroll and laboratory costs and was also facing rising legal fees as the lawsuit was dragging on for over five years.

Table 6. Yearly progress of FM broadcasting. (Erickson, p. 136)

Year	FM stations on the air	FM stations authorized	Number of FM receivers in use	Independent FM stations industry yearly losses
1945	46	55	400,000	NA
1946	55	456	500,000	NA
1947	238	918	680,000	NA
1948	587	1,020	2,000,000	NA
1949	737	865	3,500,000	NA
1950	691	732	5,500,000	NA
1951	626	699	NA	NA
1952	629	648	NA	NA
1953	594	601	NA	$ 800,000
1954	528	569	NA	$ 600,000
1955	493	552	NA	$ 400,000
1956	472	546	NA	$ 400,000
1957	530	561	NA	$ 500,000

***Table 7. Comparison of AM and FM licenses granted.* (FCC Thirty-third Annual Report, *p. 162*)**

Year	AM licenses granted	FM licenses granted
1949	200	57
1950	194	35
1951	116	15
1952	60	24
1953	187	29
1954	148	27
1955	161	27
1956	197	31

The struggle also took a physical toll on Armstrong. After suffering with symptoms that resembled a stroke, he was diagnosed with encephalitis. His recovery was slow and friends noticed the difference in his appearance. As it appeared to Marion Armstrong, her husband was not going to settle but going to fight the lawsuit to the end (Fig. 23). As this was taking a toll on her as well, she left their River House apartment deciding not to return until the lawsuit was over.

Perhaps sensing weakness in their opponent, RCA offered a settlement. This time the terms were less acceptable to Armstrong then the last offer in 1940. If Armstrong withdrew his charges against RCA, then after a period of one year, RCA could pay one million dollars for their own infringement and another one million for their licensees' infringement. Armstrong had little choice but to discuss the option with his lead attorney, Al McCormack. Seeing how despondent Armstrong had become, McCormack reminded Armstrong of his legacy that would remain no matter what the outcome of the lawsuit. He told Armstrong that of all the parties involved that it was only Armstrong's achievements that will be remembered. Armstrong replied, "Al, you don't know how little this all means when you have made a mess of your personal life."[39] He did not accept the RCA offer. In January of 1954, Armstrong met with his engineer John Bose. Bose was struck by Armstrong's appearance and condition. When he pressed the issue with Armstrong, he blamed it on a virus. Bose passed the word to some of Armstrong's friends who set up plans to meet with him. Armstrong didn't appear as he had promised.

In an article titled "E. H. Armstrong: The Hero as Inventor," the author, radioman Carl Dreher, notes that friends as well as Mrs. Armstrong recognized the toll, both mental and physical, that the struggle has taken on Howard Armstrong. Dreher stated that there are few men that could remain as devoted to a cause as Howard Armstrong. Dreher then recognizes that "beyond a certain point, devotion to a cause, however admirable, enters the realm of pathology."[40]

On Jan 31, 1954, Armstrong was far past that point. Feeling he was losing his business battles and now recognizing how he had damaged himself and his marriage, Howard Armstrong took his own life. For an individual, inventor, or businessman, to win a test of

Fig. 23. Late photo of Howard and Marion Armstrong. (Armstrong Family Archive)

endurance against a big corporation is a near impossible task. The corporation always has replacements for those tired of the battle. The corporation's warriors can end their day at 5 p.m. The individuals battling the corporation, too often, take the struggle home with them. Armstrong lost his struggle but FM, the invention, would fight on.

The estate of Edwin Howard Armstrong consisted, for the most part, of 21 unsettled law suits. Some were claims made for damages as the original patents were running out. Marion Armstrong was encouraged, by some, to just settle the cases as fast as she could and on any terms. Armstrong attorney Dana M. Raymond, who worked with Armstrong

for years, found Marion Armstrong to be "quite a woman." She took over the legal battles for the estate and continued the lawsuits that had been in progress in what she believed to be the same way her husband would have proceeded. Howard Armstrong's legacy would be vindicated.[41] As time went on, settlement was reached with RCA. A payment of $1 million was paid to the estate and soon many of the other violators decided to settle.

Attorney Dana Raymond stated that the defense in these cases made two strong points. The first was that "even if it was conceded that Armstrong made a tremendous contribution to radio and he had opened up a new line of radio by his FM work, still his discovery was too broad to be something that was covered by a patent." This goes back to the argument that the FM signal is a discovery of something in nature and all of the methods of manipulating it are too broad to be patented. The second defense was a legal technicality. This was a major point in the lawsuit against Emerson for patent violation. Their defense was explained by Raymond. He said Armstrong's invention was for an FM system utilizing a transmitter and a receiver. That would imply that the transmitter was not the invention and the receiver was not the invention but rather a system that needed both a proper transmitter and a proper receiver. Emerson's attorney, Floyd Crews used that argument for the defense when he stated "the Emerson Company has never turned on a transmitter nor has it turned one off. It has never manufactured one. All it has done is manufacture receivers and sell them to the public, and the public uses them to pick up signals that have been authorized by the Federal Communications Commission, a government agency. There hasn't been any infringement on the patent." If Armstrong were there, he certainly would have felt exiled in that world of words. The arguments did not hold up enough to convince Judge Edmund Palmieri and he found for the Armstrong estate in September 1959. Motorola was the last to fight on with a trial that began in October 1961. It finally concluded on March 22, 1967.[42] Of a total of 21 suits filed against infringing companies, all were settled or found for the Armstrong estate. The total of all the awards exceeded $10 million.[43]

Likely, Howard Armstrong would not have been so willing to settle as the terms were not that different than earlier offers, ones he had turned down in the past. One can only conjecture that had there been just a few little changes in the chain of events in the development FM, that story could have had a very different ending.

New Audiences for FM

Now FM would have to battle for itself. Proponents of FM would continue to find ways to use and improve FM. The use of FM for ground communications continued to grow as more and more police and government agencies used FM. It was the method of choice to relay news and programming from remote events to the radio station for broadcast. FM relays continued to link stations together and save the cost of

renting telephone lines. The FCC would approve using multiplex broadcasting for transmitting subscription channels. Soon Muzak and others like it would fill elevators and hallways with nonstop easy listening music. This service would help generate needed revenue for the broadcaster. In 1963, the FCC approved FM stereo broadcasting, using a method proposed by Zenith. Now FM stereo gave music fans an additional reason to choose FM. Also, a younger generation of music fans turned to FM for rock stations, which opened up more music choices than the limited "Top 40" format of AM stations, which played mostly the same music. The option for AM-FM stations to duplicate broadcasting was phased out by the FCC. FM also became the place to go for jazz, folk, and other genres along with the classical stations that were there from the beginning.

From the beginning of FM broadcasting, Armstrong gave a free license to educational broadcasters. As time went on, public radio and listener funded stations were added to list of broadcasters. As new transistorized portable radios added FM to their capabilities, listenership got another boost. As listenership increased, advertising increased and revenue increased.

Hi-Fi

Armstrong was not the only one disappointed in the performance of the FM radios that were being produced. It was also noticed by a group that had found a niche as FM enthusiasts. Many of the independent FM stations that were suffering from financial hardship had to reduce costs. They had to reduce programming costs and did this by programming music from transcription or long-playing records. To find a niche of listeners that the bigger stations ignored, they found lovers of good music. This music was primarily classical and light classical.

When, not only the FM radios, but also the phonographs that were available, did not live up to the expectations that buyers demanded, a new business developed to answer the need. This new business was called Hi-Fi. The term high fidelity had been used to describe the improvement needed in AM radio, but soon the term Hi-Fi would describe the equipment built for these fans of good music. The enthusiasts knew that the potential of FM was an audio response from 30 Hz to 30,000 Hz. Analysis of the high-grade radios that were produced by the major manufacturers was disappointing. The frequency range 200 Hz to 4,000 Hz was considered good, as costs were kept low by using inexpensive and poorly designed speakers and audio amplifiers.

Soon an entire industry would form to answer the needs of many music fans who demanded something better than radios that the general radio manufacturers were producing. Some buyers were interested in the improved technology, while others just wanted something that sounded good. One of the first companies formed to answer the call was Radio Craftsmen, 4401 North Ravenswood Ave., Chicago, IL. Radio Craftsmen was formed in 1947 by former Hallicrafters Radio Company executive John

Cashman. He chose the location in a part of Chicago that was also the home of Zenith, E. H. Scott Radio Labs, Stancor, Halldorson, and others in the electronics business.[44] They were one of the first companies to offer audio components, giving the buyer the opportunity to mix, match, and upgrade parts of their system. Other companies such as Howard, GE, Meissner, and Pilot were designing and building nice sounding and nice looking FM tuners also (Fig. 24); these had a line-level audio output that you fed to the phono input of your Hi-Fi system.

In 1947 the Craftsman model RC 1 AM-FM Tuner was introduced as well as the RC 2 Audio Amplifier. Soon talented engineers Ed Miller and Sid Smith joined Craftsman. In 1949, the RC 10 tuner was introduced (Fig. 25). Perhaps their audio component products were somewhat ahead of their time. Marketing

Fig. 24. Early FM converters (tuners) to bring FM to your AM radio or phonograph system; clockwise from upper left: Howard model 482, 1950; General Electric model XFM-1 FM translator, 1949; Meissner "Brewster" 8C, 1947; Pilot Radio "Pilotuner" T601, 1947. (Author's Collection)

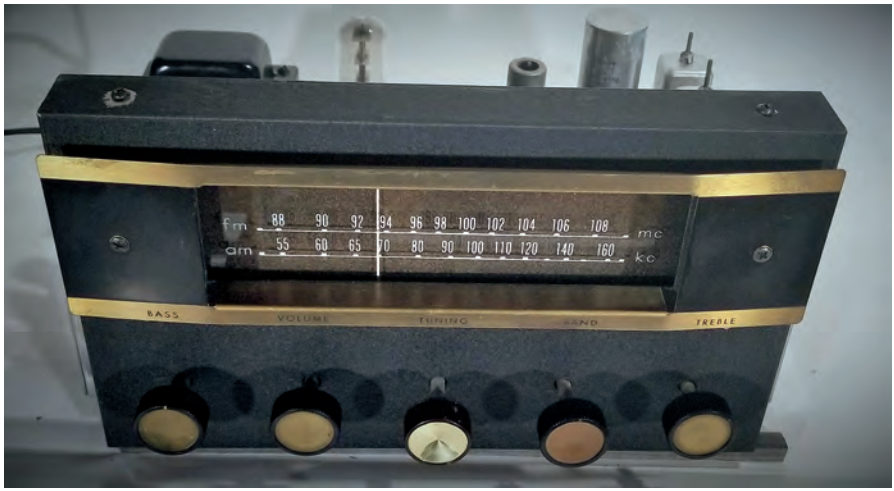


Fig. 25. Radio Craftsmen model RC-10 AM-FM tuner, 1949. One of the better early new band FM tuners. (Author's Collection)

through mail order outlets like Lafayette and Allied was not working out, and the company closed in 1955. Sid Smith joined the new Marantz Company and Ed Miller started Sherwood Electronic Laboratories. At this time, other audio companies were formed with the last names of their founders as Saul Marantz, Frank McIntosh, Hermon H. Scott and Avery Fisher.[45] Desire for the quality sound of their FM tuners and other components answered a demand that the home radio manufacturers passed up. These listeners helped spur the growth of the FM broadcasters.

Armstrong had one FM license holder that may well have been a favorite. Radio Engineering Laboratories (REL) in Long Island City, New York was an early FM license holder building transmitters and broadcast equipment. At times Armstrong had a personal interest in the company and later Armstrong friend, George Burghard, became owner of the company. The only consumer product the company produced was an FM tuner named the Precedent (Fig. 26). The design was the work of two REL engineers, Benji Hara and George Pappamarcos. If Armstrong had seen the design he certainly would have smiled. The 15-tube, FM mono tuner was built to get everything from the FM signal (Fig. 27). The operator controls included AF gain, RF gain and tuning. There is no tuning condenser as the design uses permeability tuning. The 15-tube circuit features a cascode front end (two tubes), four tuned IF stages, one untuned IF stage, three prelimiter stages, two limiter tubes, two solid state diodes in the discriminator, two audio amplifier tubes, and one rectifier.

As the 1950s turned into the 1960s, the interest in Hi-Fi equipment broadened and products were designed for

Fig. 26. REL Precedent FM tuner, considered the best of its time. (Author's Collection)

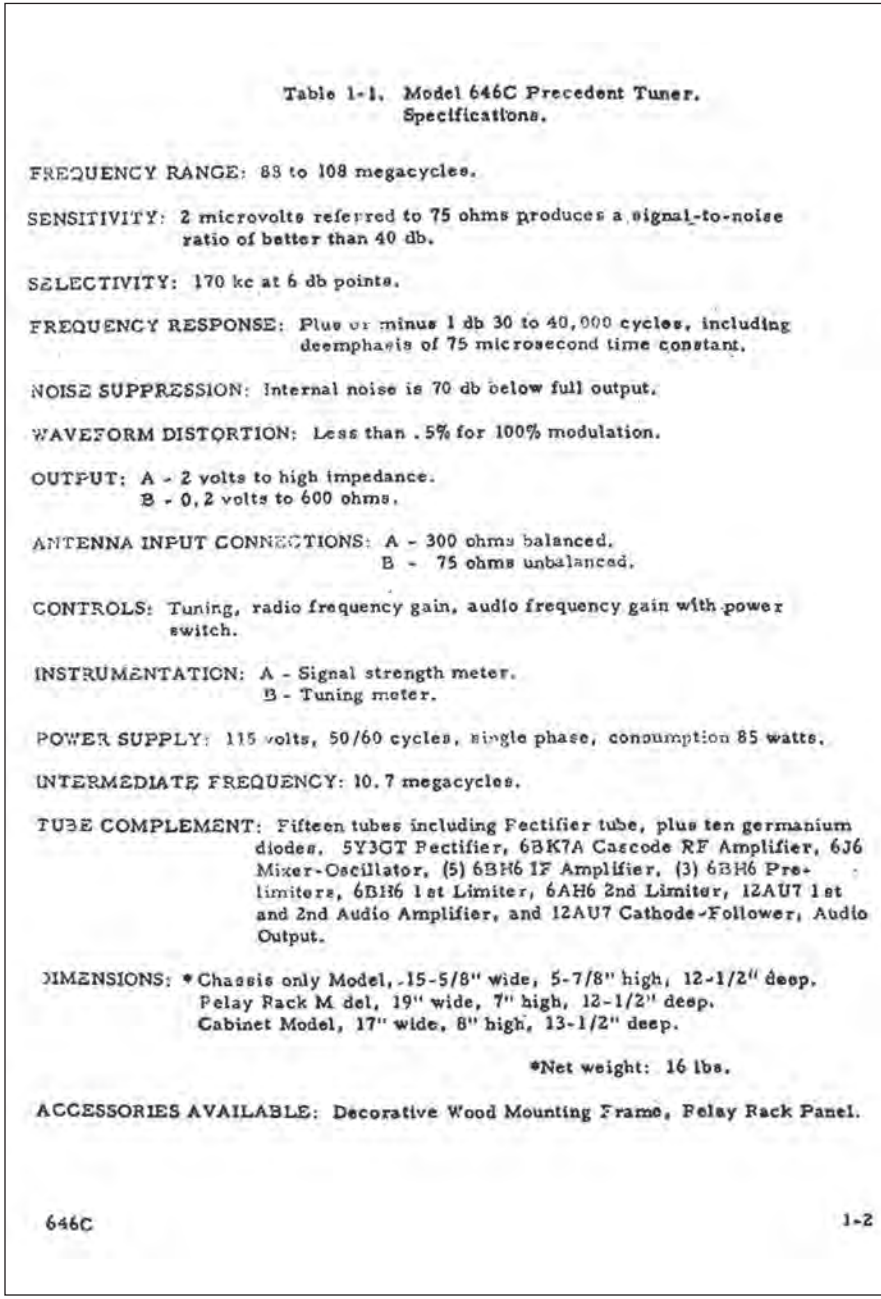


Table 1-1. Model 646C Precedent Tuner.
Specifications.

FREQUENCY RANGE: 88 to 108 megacycles.

SENSITIVITY: 2 microvolts referred to 75 ohms produces a signal-to-noise ratio of better than 40 db.

SELECTIVITY: 170 kc at 6 db points.

FREQUENCY RESPONSE: Plus or minus 1 db 30 to 40,000 cycles, including deemphasis of 75 microsecond time constant.

NOISE SUPPRESSION: Internal noise is 70 db below full output.

WAVEFORM DISTORTION: Less than .5% for 100% modulation.

OUTPUT: A - 2 volts to high impedance.
B - 0.2 volts to 600 ohms.

ANTENNA INPUT CONNECTIONS: A - 300 ohms balanced.
B - 75 ohms unbalanced.

CONTROLS: Tuning, radio frequency gain, audio frequency gain with power switch.

INSTRUMENTATION: A - Signal strength meter.
B - Tuning meter.

POWER SUPPLY: 115 volts, 50/60 cycles, single phase, consumption 85 watts.

INTERMEDIATE FREQUENCY: 10.7 megacycles.

TUBE COMPLEMENT: Fifteen tubes including Rectifier tube, plus ten germanium diodes. 5Y3GT Rectifier, 6BK7A Cascode RF Amplifier, 6J6 Mixer-Oscillator, (5) 6BH6 IF Amplifier, (3) 6BH6 Pre-limiters, 6BH6 1st Limiter, 6AH6 2nd Limiter, 12AU7 1st and 2nd Audio Amplifier, and 12AU7 Cathode-Follower, Audio Output.

DIMENSIONS: *Chassis only Model, 15-5/8" wide, 5-7/8" high, 12-1/2" deep.
Relay Rack Model, 19" wide, 7" high, 12-1/2" deep.
Cabinet Model, 17" wide, 8" high, 13-1/2" deep.

*Net weight: 16 lbs.

ACCESSORIES AVAILABLE: Decorative Wood Mounting Frame, Relay Rack Panel.

646C 1-2

Fig. 27. Specification sheet for REL Precedent model 646C FM tuner. It used 15 tubes. (Author's Collection)

a lower end market. Simpler and less expensive design for AM-FM tuners became basically two receivers sharing one power supply. These sets can be quickly identified by the use of two separate tuning dials (Fig. 28). As in this

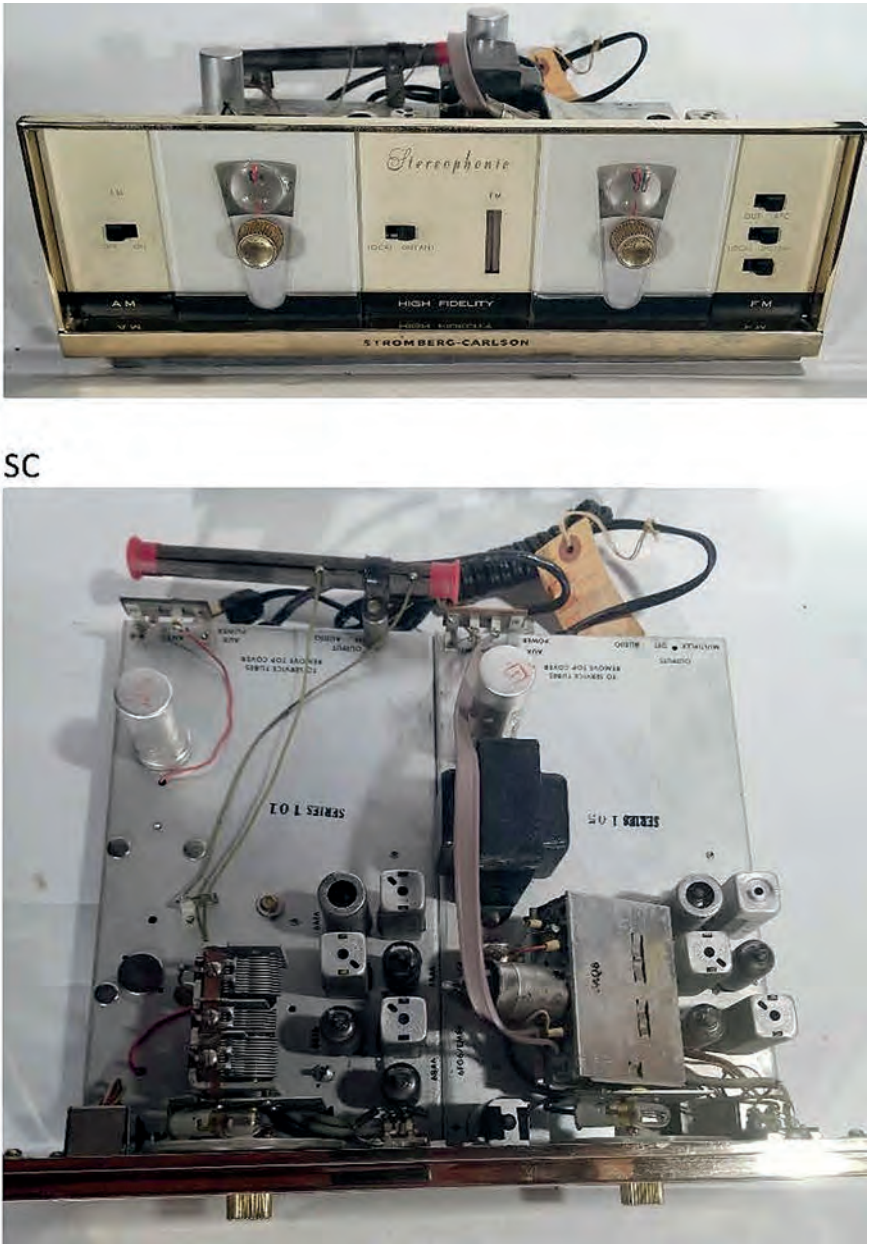


Fig. 28. Stromberg-Carlson model RS-440, an early Hi-Fi AM-FM tuner. (Author's Collection)

Stromberg-Carlson RS440, there are two tuning condensers on two separate chassis side by side. As the number of Hi-Fi enthusiasts now spanned high end as well as lower priced equipment, the number of FM listeners continued to grow.

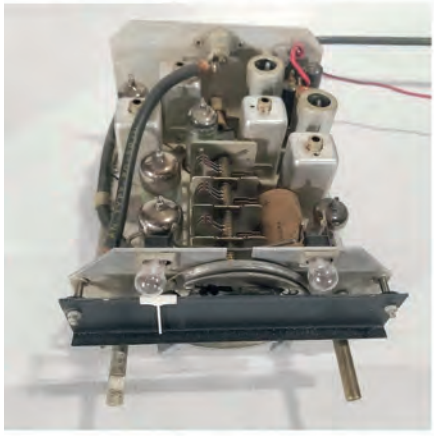
Car FM and Converters

As the war ended and America was buying cars, America took to the road. But the crackling and fading of the AM car radios must have been quite a distraction. Those push button tuning systems took a beating as drivers kept going back and forth to see if a favorite station might have drifted back in range.

With the vacuum tube technology, AM car radios slowly advanced in the 1940s. An FM car radio would be an even bigger challenge. One approach to getting FM on the road was to produce an FM converter. This clever innovation included a compact FM tuner with no audio section. The output of the detector was then fed into a simple AM modulator, which was attached to the car AM radio. The station received by the FM tuner was received by the AM radio like any AM broadcast station. Although the system worked, there were deficiencies. The quality of the audio circuits and speaker system was far below the audio potential of an FM receiver. Also, outside static would be rejected by the FM radio but still received by the AM radio.

Faust Gonset, W6VR, and his company, Gonset Inc. of West Hartford, CT was best known for the Gonset Communicator series of VHF transceivers. They produced ham radio and other products, some for automotive use. In the late 1950s, they were one of the first companies to produce FM converters, designed to be mounted under the dashboard. The converter ran off the 12 volt car voltage and did not use a vibrator to convert the DC. The seven-tube circuit used space charge tubes with 12 volt plate voltages (Fig. 29). An FM-only

GONSET model 3239 1959 FM Converter



Gonset FM converter 7 tube chassis

Fig. 29. Gonset model 3239 FM converter, 1959, showing the seven-tube chassis, brings FM to your car's AM radio. This tuned and demodulated the FM frequencies, then modulated as AM and output an AM radio frequency. (Author's Collection)

car radio was first introduced in this country as an import from Blaupunkt. It came installed in some Mercedes. The next year an AM-FM radio, the Becker Mexico, was introduced.

Motorola had produced an FM converter and FM receivers for home use in 1942 on the pre-war FM band. They also produced post-war FM receivers through the 1940s and early 50s, and were a major producer of FM communication radios for the government and police departments. Motorola was one of the patent violators claiming protection under RCA patents and later, claiming Armstrong did not properly inform Motorola of their infringement. Motorola had paid no royalties during this entire period. Before a legal time limit expired, Armstrong filed an infringement suit in January 1954. Marion Armstrong later pursued the suit against Motorola. Appealing loss after loss up to the Supreme Court, the Armstrong estate, after 13 years, won a complete victory over Motorola in 1967.

That period behind them as the original FM patents had expired, Motorola continued as a leader in FM products. Seeing that no U.S. manufacturers had plans to produce an FM car radio, management decided, in 1959, to take on the project. The company wanted to take full advantage of the sound quality possible with a well-designed full receiver to be added under the dashboard. The FM 900, produced in 1960, was the result (Fig. 30). This design was innovative, using a separate power supply for placement behind the dashboard. Ahead of its time, the power supply used one transistor as a switching power supply to produce plate voltages for the seven tubes. The hybrid design used two transistors in a push-pull audio output circuit. The story of the design and production of this radio is told in the *AWA Review* article "The First Broadcast FM Auto Radio—Motorola FM-900" by two of the men (Fig. 31) that made it happen, design engineer Ray Schulenberg and production engineer Olin Schuler.[46]

In 1962 management at Motorola saw that there was strong demand for a good FM converter. The model FMC 62 was a seven-tube unit with a sleek, modern look (Fig. 32). This set ran on 12 volts and mounted under the dash. It was a superhet design with permeability tuning. There were no audio stages but the detector output was fed into an AM modulator sending the signal out at 1400 kHz. The car antenna enters the converter and is either passed through to the AM radio or is converted by the FM tuner and then sent to the AM radio. Many AM car radios at the time had push button tuning. This would allow the owner to set one of the buttons to 1400 kHz and be ready for the converter's output. As transistor technology made these converters smaller and cheaper, many manufacturers introduced converters, bringing FM into many cars. These new Hi-Fi tuners, car radios, and converters added a loyal new audience for FM stations.

Motorola—and only Motorola—offers you an *FM-only* car radio—with tonal quality you'd expect from a console

Now there's no need to leave good music behind when you leave home and go out for a drive.

Motorola fired up its FM-900 car radio with a record 15 watts of peak power output to bring you FM music with unmatched clarity and brilliance.

This remarkable FM radio operates independent of your present AM set, carries a full year guarantee.* A flick of the dual speaker control brings all the fine music directly to your back-seat passengers.

New FM radio fits under the dash, reinstalls easily so you can take it with you when you trade cars.

Worth every penny of the $125** it costs. Now at Motorola dealers.

● MOTOROLA—*new leader in the lively art of electronics*

*Manufacturer's guarantee covers free exchange or repair of any component proven defective in normal use. Removal and reinstallation labor included. Arranged through selling dealer. **Manufacturer's suggested retail price. Installation and antenna extra. Price and specifications subject to change without notice.

Fig. 30. Original advertising art for the Motorola FM-900 under dash car FM radio. This was a complete FM-only radio with audio power output of 15 watts. (Author's Collection)

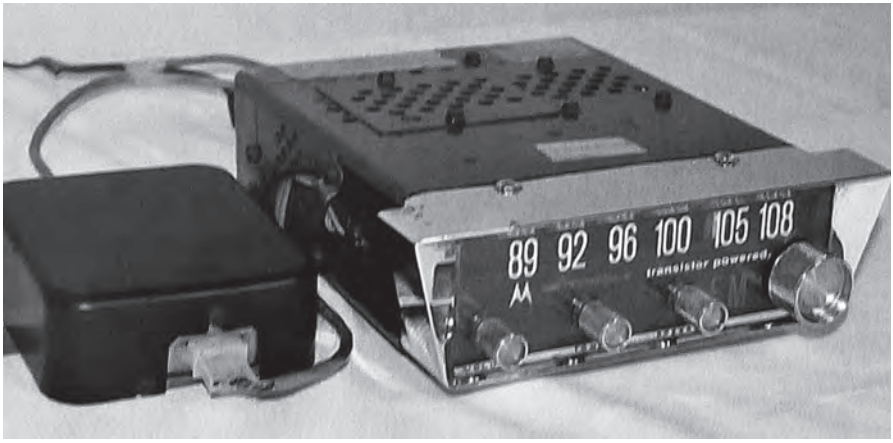


Fig. 31. Photo of the Motorola FM-900 under dash car FM radio, 1959. Also shown at left is the dual speaker control to bring music to your back-seat passengers. ("The First Broadcast FM Auto Radio–Motorola FM-900," *AWA Review,* Vol. 28, 2015, p. 75)

Fig. 32. Motorola model FMC-62 under dash car FM converter 1962. (Author's Collection)

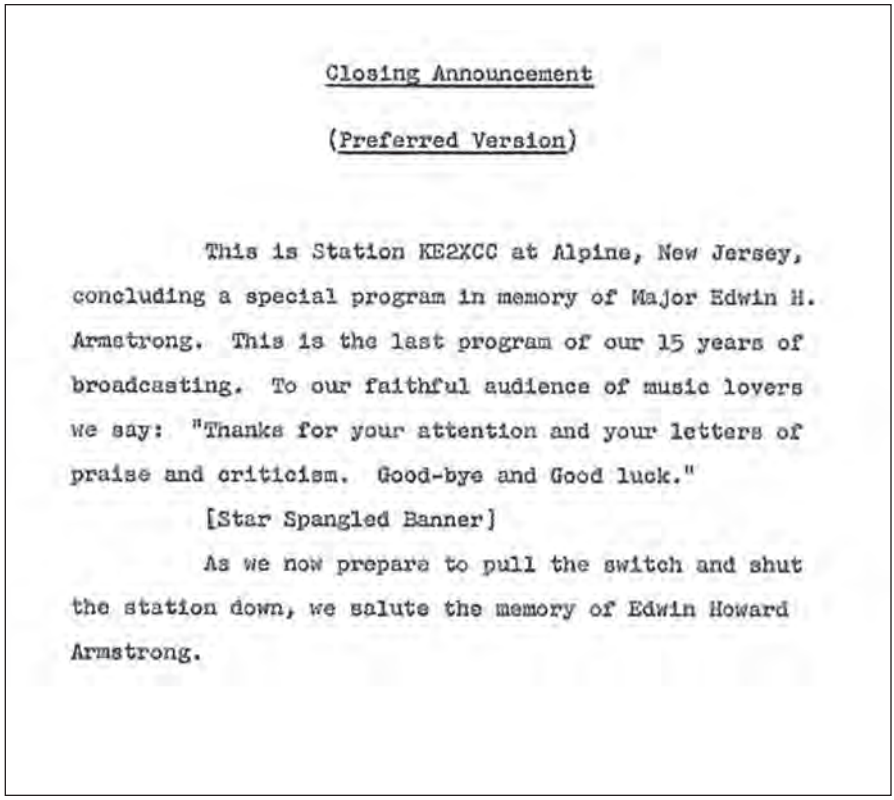
Conclusion

After Armstrong's encouragement, congressional hearings investigated the action of the big money interests in radio as well as the actions of the FCC. As often happens with these hearings, testimony was given, problems and blame were documented, recommendations were made, and then little change, if any, occurred. Over time many of the regulations on FM would be lifted or modified. The damage caused to both FM and UHF television broadcasters had been done. In the hearings for frequency allocations, FM was moved from the 50 MHz band, and television channel 1 was put in its place. Armstrong testified that the entire television allocation would not work. He calculated that the TV channels 1 to 13 would have interference problems between adjacent channels. It was suggested that the entire TV band be moved up to the TV UHF band before regular broadcasting got under way, but this request was denied. That prediction immediately proved to be correct and each major city would have to skip a channel number to avoid interference. This resulted in TV Channel 1, which was in the pre-war FM band, being deleted. That band came to be used for police and emergency services. The predicted interference to the old FM band never happened. It was little comfort to be proven right after the damage was done.

On one hand, the opponents of FM did have some victories. Armstrong's prediction that in five years FM would supersede AM never happened as he envisioned it. AM still lives and FM had to learn to coexist. The broadcasting monopolies that were at first threatened by FM, survived and thrived. Over time the same problems of big corporations controlling broadcasting have now included FM. If that was the entire goal of the FM opponents, that victory is theirs.

FM had the stamina and has passed the endurance challenge. Not only in broadcasting but also in communication equipment, relay equipment, and many other applications. It wouldn't be until the 1960s that the financial situation at independent FM broadcasting, as a whole, began to improve.[47] Sadly, with so much stacked against him, Howard Armstrong did not survive the endurance challenge. In his eulogy of Armstrong, radio man Carl Dreher told of Armstrong's accomplishments. After it was published, Dreher received a letter from Lee De Forest challenging Dreher's statements crediting Armstrong with inventions that were later contested or overturned on legal grounds. Dreher responded to the letter saying that every engineering opinion supported Armstrong. He noted that the older radiomen and engineers know what really happened and the younger ones, he said, "just don't give a damn."[48] I have to contend that Armstrong's four great inventions, regeneration (feedback), superheterodyne, super-regeneration and frequency modulation, live on in various forms. Today, engineers using these concepts in new equipment can appreciate what came before them. Also, anyone who enjoys using or repairing older radio equipment sees the original concepts at work and should think

back at how much genius came from one man. Groups exist today to keep the memory of Armstrong's legacy alive. After his death, Armstrong's research and operations were closed down. The Alpine station KE2XCC, formerly W2XMN, ended years of broadcasting. A copy of the closing statement is in the Armstrong archive at the Columbia University Library (Fig. 33). Today, many will still salute the memory of Edwin Howard Armstrong.



Closing Announcement

(Preferred Version)

This is Station KE2XCC at Alpine, New Jersey, concluding a special program in memory of Major Edwin H. Armstrong. This is the last program of our 15 years of broadcasting. To our faithful audience of music lovers we say: "Thanks for your attention and your letters of praise and criticism. Good-bye and Good luck."

[Star Spangled Banner]

As we now prepare to pull the switch and shut the station down, we salute the memory of Edwin Howard Armstrong.

Fig. 33. Closing Announcement prepared for the last broadcast by Armstrong's FM station KE2XCC, formerly W2XMN, Alpine, NJ. (Poppele Collection FM Scrapbooks, AWA Museum)

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About the Author

Mike Molnar is still running Diagnostic Services Inc., the company he started in 1983, although the pandemic may have slowed things down. He builds and services nuclear medicine equipment, mostly for the veterinary market; this has been more of a challenge with travel restrictions but somehow business keeps moving along. Now Mike is suffering from radio meet withdrawal symptoms, a problem he hopes to recover from in the next few months. He has had the time to add a few radios to his collection of electronic fossils, some of which he has now had for over 50 years. All are invited to check his website at www.electronicfossil.org.

Author Mike Molnar (right) and assistant Lila maintain safe standards while collecting radios and other electronic fossils.

prelude to Armageddon: Wireless Super Stations and Imperialism

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This is not a novel nor is it a strictly historical treatise; it is a rendition of the circumstances and events that brought the fledgling phenomena of wireless to the Great War. Step-by-step, successively war-by-war, wireless became more advantageous to the combatants, and bound the great powers to their worldwide empires.

General

The man of the hour was the Italian inventor Guglielmo Marconi. His genius was to be challenged as the world was on the verge of a series of wars, which were the prelude to the big one: The War To End All Wars. These wars were the first in which innovative weapons such as machine guns, grenades, airplanes, armored vehicles, as well as wireless, were utilized. Shown in Fig. 1 is Guglielmo Marconi: Senator Of The Realm Of Italy; Nobel Prize Recipient.

As the cosmic clock advanced into the twentieth century, the wireless accomplishments of the Marconi Wireless Telegraph & Signal Company had increasingly astonished the world. Their signals were leaping greater distances and linking ships, and as we will see, countries, and ultimately, continents. And the wireless future was unlimited.

This future was to include the annexation of Africa, for this was the era of European Imperialism in Africa. A map of imperialist Africa in 1914 is shown in Fig. 2. European nations scrambled for positions of colonization and trade amongst the weakly governed territories, which afforded the prospect of immensely valued resources. Colonization also had the effect of avoiding conflict among themselves. "Fragile diplomacy" was

Fig. 1. Guglielmo Marconi—Senator Of The Realm Of Italy—Nobel Prize Recipient. (https://www.nobelprize.org/prizes/physics/1909/marconi/biographical/)

the method of regulating the division of the spheres of influence among the great powers. Countries that had colonies in 1900 Africa were Britain, France, Portugal, Germany, Belgium, Italy, and Spain; all these are shown in Fig. 3. These countries were exploiting the natural resources as shown in Fig. 4.

Local administration was conducted by commissions and chartered trading companies. These methods essentially required reliable communications with

Fig. 2. Imperialist Africa 1914. (https://www.imperial+africa+map&sxsrf=ALeKk01dIC9QYtVaJ1GkJeGneuW5Py6x0A:)

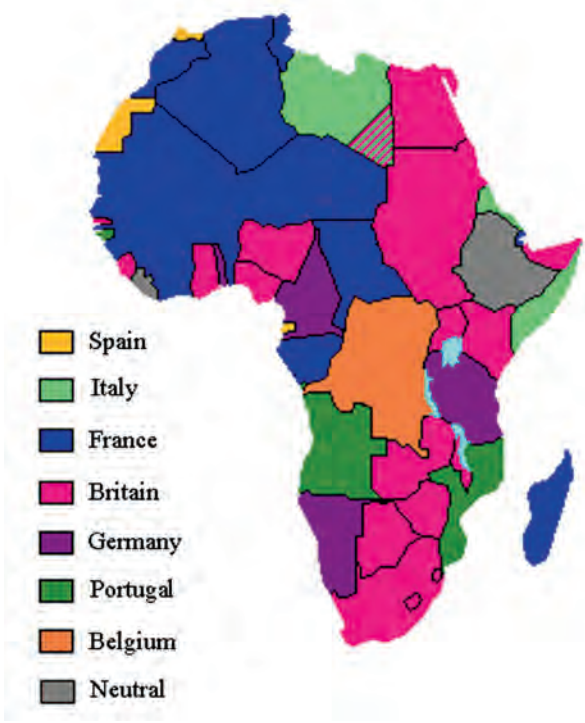

Fig. 3. Countries that had colonies in Africa, 1900. ((https://www.imperial+africa+map&sxsrf=ALeKk01dIC9QYtVaJ1GkJeGneuW5Py6x0A:))

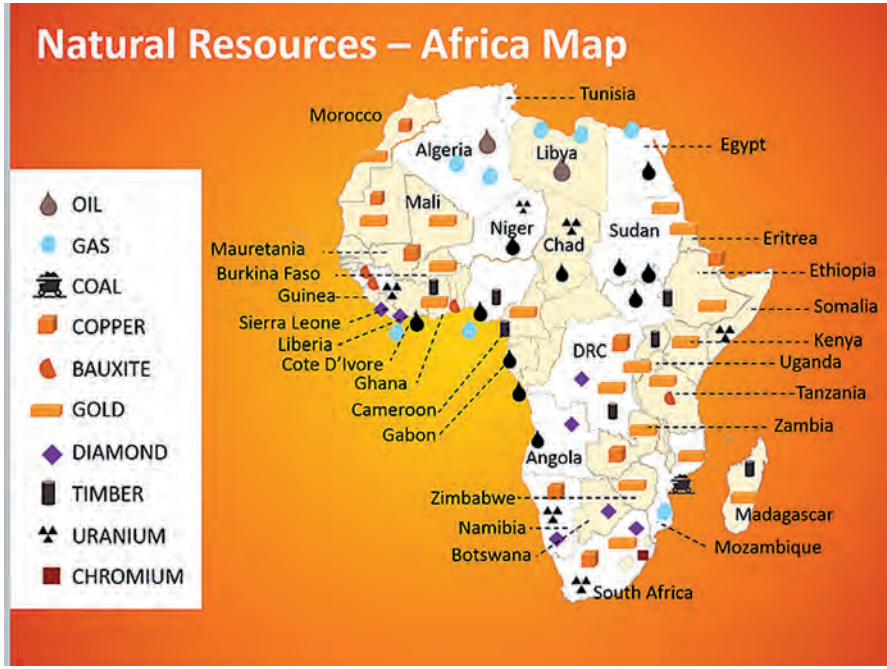

Fig. 4. Natural resources—Africa Map. ((https://www.imperial+africa+map&sxsrf=ALeKk01dIC9QYtVaJ1GkJeGneuW5Py6x0A:))

the European authorities. Initially, the various entities utilized sailing vessels to conduct their transcontinental post between ports. Internally, local communications improved with the development of railroads and roads, which supported telegraph lines. British All Red Line[1] world telegraphs[2] linking the British Empire are shown in Fig. 5, while all the world's telegraphs are shown in Fig. 6.

Britain dominated the land route having created an inter-Africa infrastructure.

Fig. 5. Red Line world telegraphs. (George Johnson (1836–1911) – The All Red Line – (https://www.imperial+africa+map&sxsrf=ALeKk01dIC9QYtVaJ1GkJeGneuW5Py6x0A:))

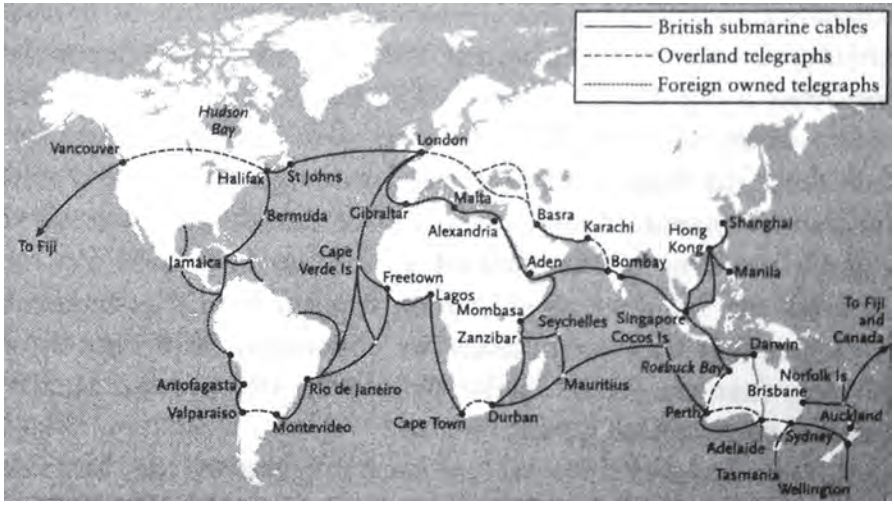

Fig. 6. World telegraphs. (https://www.imperial+africa+map&sxsrf=ALeKk01dIC9QYtVaJ1GkJeGneuW5Py6x0A:)

This was the first global communications surveillance system, running from Cairo to Cape Town, and from Gibraltar to Zanzibar. Progressing even further by 1911, the British had completed the All Red Line undersea cable system, which linked their entire worldwide empire.

Boer War—Britain

At first, occupation was effected by trading companies chartered by the dominating country, followed by colonization, in the areas of mining resources and farming. The extent and means of control varied by the resources available beyond trade goods. Britain was the most successful and powerful of the occupying nations controlling the rich south and southeast areas of the continent. However, control of these territories did not come peacefully. The "Masters of Imperialism" encountered serious opposition to their domineering efforts, as shown in Fig. 7.

Britain fought the Anglo-Zulu War against the powerful kingdom in 1879 and the Boer War against the renegade Boer states of Transvaal and the Orange Free State from 1899 to 1902. A picture of the conflict is shown in Fig. 8.

The Boer War was the first to utilize the invisible weapon—wireless. Wireless was the phenomena which was to positively change the world and here began to alter the manner of conduct of war, or was it to bring an end to war? Marconi's Wireless Telegraph & Signal Company had successfully obtained the approval and endorsement of the British government just three years prior to the insurrection.

The British Army initially engaged with the Marconi entity for five portable stations supported by six engineers. The original intent was to utilize the stations to coordinate the ship to shore activities of the disembarkation of the

Fig. 7. Boer War: Britain. (https://www.google.com/search?q=boer+war&sxsrf=ALeKk00fCYRszUaS4nOSxb42uxqZpo9cYQ)

Fig. 8. Britain vs Zulu. (https://www.military-history.org/articles/3-popular-myths-of-isandlwana-1879-zulu-war.htm)

troop and cargo vessels. But, the stations were quickly deployed to urgent army field activities where performance of the sophisticated equipment proved to be less than successful.[3] Reliability and consistency were affected by problems that arose with antennas, grounding, and frequent and severe electrical and dust storms. An early Marconi key is shown in Fig. 9, a field radio in Fig. 10, some Siemens apparatus in Fig. 11, and some Marconi apparatus in Fig. 12.

As the nature of the war became highly mobile, the fixed station equipment was taken over by the British Navy. The navy fitted the equipment to each of five cruisers whose masts were extended to permit the rigging of long wire antennas. This operation was highly successful with a distance of 290 miles reportedly achieved.

Fig. 9. Early Marconi key. (https://www.google.com/search?q=marconi+telegraph+key&sxsrf=BAgNEAE#imgrc=f5brZVlzLDDgsM)

Fig. 10. Field radio. (https://samilitaryhistory.org/vol112db.html)

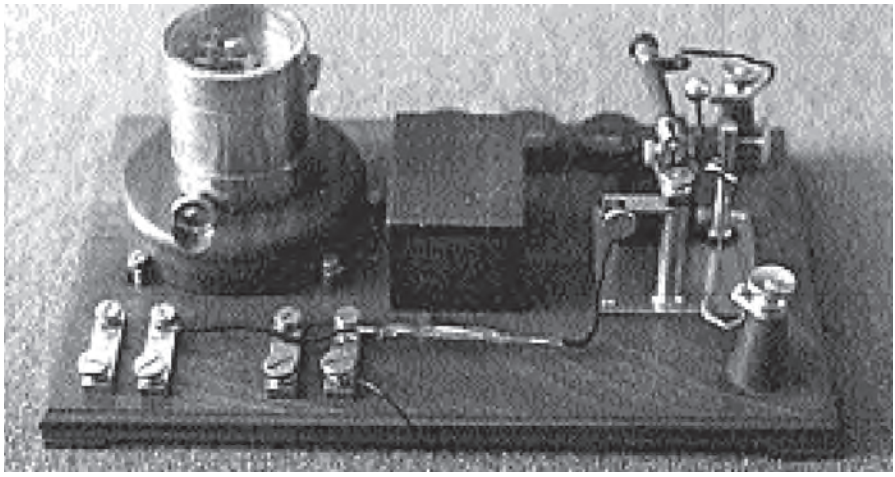

Fig. 11. Siemens apparatus as used in Boer War. (http://samilitaryhistory.org/vol112db.html)

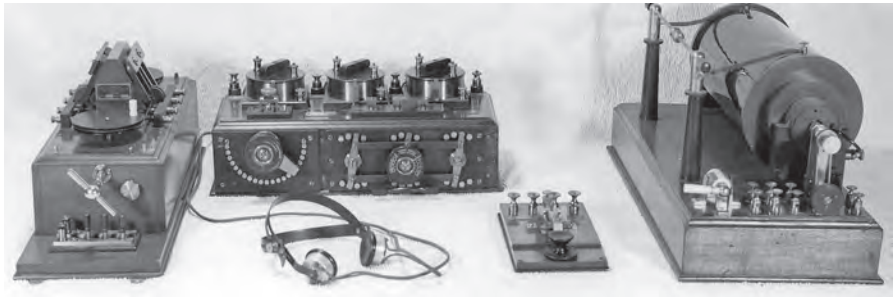

Fig. 12. Four pieces of Marconi equipment. (Society of Wireless Pioneers, California Historical Radio Society)

German East Africa

After the "Scramble for Africa" among the major European powers in the 1880s, Germany reinforced its hold on several formal African colonies. These were German East Africa and German Southwest Africa, extensive territories centered on Lake Victoria, and comparable in size to the expanse under the then British influence.[4] Of the two, the East Africa area was the more volatile and most resistant to control. German rule there was ruthless, seeking to extract maximum labor and material benefits from the natives. The area occupied by Germany in East Africa is shown in Fig. 13.

The province was constantly in a state of disturbance with guerilla tactics prevalent. The stringent policies intensified, igniting the major Maji Maji Rebellion in 1905, an armed uprising of Islamic and Animist Africans against the colonial rule. The upheaval continued through 1907 and left the indigenous population decimated by enormous losses and famine.

Fig. 13. German East Africa (green). (https://www.google.com/search?q=german+east+africa&sxsrf=ALeKk027xElOLL)

Eritrea and Libya—Italy

As the new century dawned, Italy's ambition for African possessions intensified, and was modestly satisfied by the formalization of a treaty grant in 1896, of a portion of Ethiopia. This was intended to lead to the annexation of parts of the remainder of Ethiopia. Attempts to accomplish this by arms were unsuccessful and the Italians focused their attention on North Africa and the evacuation of the Ottoman Turks.

Libya was appealing to the Romans as a possession reminiscent of the ancient city of Carthage (now Tunis, Algeria) and the Roman Empire. Anxious to emulate other expanding imperialistic European partners, the Kingdom of Italy coveted the African Ottoman provinces to its south directly across the Mar Nostrum (Mediterranean) from Sicily. The North African area, commonly known as Tripolitania, was invaded in 1911 by sea and land. This was the first war to be fought on land, sea, and from the air.

The Turks had been interested in wireless for some time prior to this war. They supported field trials between the Marconi and German Telefunken systems. The Marconi system prevailed in every respect. However, the Turks elected to begin equipping their few vessels with the German system as they were seeking their alliance. Several major Libyan port cities were equipped with wireless capable of communicating with Constantinople. However, these were rapidly disabled by Italian naval fire. Field wireless was not within the capability of the Islamist defenders who relied mostly on traditional desert warfare methods.

The Italians used wireless extensively in their campaign, and once underway, the Minister of Maritime asked Sr. Guglielmo Marconi to personally inspect the wireless systems.[5] The Minister of Maritime placed the armored cruiser *R.N. Pisa* at his disposal. Long distance communications had been established with the Marconi superstation at Coltano, in Tuscany, on the 7,000 meter wavelength. Claimed to be the most powerful in the world, this 14 kilowatt spark gap installation was one of the last massive spark type generating stations constructed. It became the central clearing station for the Libyan operation.

Critically needed and crucial to the outcome of the conflict was mobile communications. More than a dozen mobile field stations, transported by camel, were designed to communicate from the desert to the higher echelon stations on the coast. And "knapsack" stations provided signals for short distance messaging of up to 15 miles. Fig. 14 shows a camel hauling around the heavy radio equipment. Camels were also used to haul other heavy equipment used in war.

By October of 1912, the pseudo land war was at a stalemate and the Italians sought an end to the hostilities. A treaty was engaged and an uneasy cessation ensued.

Fig. 14. Wireless by camel. (By Luigi Sacco - Archivio fotografico Luigi Sacco, Public Domain, https://commons.wikimedia.org/w/index.php?curid=79796302)

The Great Stations

Italy: Station ICC

This war was the final direct step to World War I as it revealed the inherent weakness of the Ottoman (Turkish) Empire and encouraged the subsequent rebellion and war in the Balkans.

The man of the hour was indeed inventor Guglielmo Marconi. His concepts and experiences masterminded the erection of two advanced spark gap transmitter stations in Europe. A giant leap forward for wireless technology, these stations were conceived with communications to Africa the paramount objective. Each stunned the world with their global abilities. Both stations followed the progression of radio technology through World War II, and one remains in operation today. At any one time the stations presented the leading edge in transmitter technology evolving from spark gap, to alternator generated VLF, to the ultimate continuous wave short wave. The Italian station ICC is shown in Fig. 15.

Fig. 15. Italian station ICC. (https://www.researchgate.net/figure/1911-Coltano-landscape-and-skyline-with-towers-radio)

The Marconi ultimate spark-gap station was established at Coltano, Italy, specifically to communicate with Africa. Did the Italian government, and its allies, plan the annexation and invasion of the Libyan Turkish-controlled provinces knowing that the new Marconi station at Coltano would provide an essential long distance wireless conduit? Yes, indeed they did!

A receiving station was situated north at Nordica, permitting duplex operation. A chronology of all stations is shown in Table 1. The superstation was named "G. Marconi," and utilized the call letters ICC. The initial transmitter specifications are shown in Table 2.

Concerning antennas, there were two sets of directional antennas–the "Colonial Aerial" pointed 130 degrees towards Africa and the station at Massawa, Eritrea, and the "Continental Aerial" pointed 300–310 degrees to Glace Bay, Nova Scotia, and Clifden, Ireland, respectively. Each of the two aerials was comprised of 24 wires, each 1,740 feet in length supported by eight towers, each 250 feet high. It was an immense installation, only to be surpassed later by the Marconi installations at Marion, Massachusetts, and New Brunswick, New Jersey. The successful communication path to Massawa, over 2,200 miles of desert, was considered a significant achievement, as heretofore the Sahara's dry soil was considered an insurmountable obstacle to low frequency waves.

After testing, Marconi himself inaugurated the station on November 19, 1911, by demonstrating its long distance capabilities to the King of Italy.

On November 30, Marconi, at the request of the Minister of Maritime, boarded the cruiser *R.N. Pisa,* to tour the Libyan wireless installations and address the difficulties of short-range communications in the desert.

Table 1. Chronology of stations. (Author's collection)

Event	Date
First Signal Sent	Nov. 19, 1911
Libyan Annexation/Invasion	Nov. 5, 1911
Prior and Existing Principal Sister Stations:	
Poldhu (England)	Dec. 12, 1901
Glace Bay (Nova Scotia)	Dec. 5, 1902
Crookhaven, (Ireland)	1902
Cape Cod (Massachusetts)	Jan. 18, 1903
Caernarvon (Wales)	1914
New Brunswick (New Jersey)	1914
Cape Cod (Massachusetts)	1918

Table 2. Transmitter specifications. (Author's collection)

Type:	Spark Gap
Radiated Power:	14 kW
Band:	Longwave (VLF)
Carrier Frequency:	43 kHz
Carrier Wavelength:	7000 m

Germany: Station POZ

The new rival station, given the call letters POZ, which after inception also claimed to be the world's most powerful at times, was constructed by the Telefunken Corporation as an experimental station in 1906.[6] The oldest continuously operating transmitting operation in the world, it is located at Brandenburg, Germany. Commercial service was continued in 1913 with a 100 kW quenched spark gap transmitter superseded by a 100 kW alternator continuous wave transmitter. This fed an omnidirectional umbrella antenna consisting of a directional flattop array comprised of 20 parallel horizontal wires with a total length of 33,400 feet, supported by five towers, each 390 feet high. This arrangement was purported to be the world's most powerful, signaling a range of 5,600 miles. Essentially, station POZ was capable of communicating to its sister station in the United States at Sayville, Long Island, New York, during daylight hours. This early Nauen station is shown in Fig. 16.

Fig. 16. Early Nauen station. (https://en.wikipedia.org/wiki/Nauen_Transmitter_Station#/media/File:Bundesarchiv_Bild_10)

The European (and African) War

In 1914, shots were fired in Sarajevo, treaty alliance obligations actuated, and the central European continent found itself in an enormous ghastly war. During this period innovative methods of warfare, such as machine guns, aerial bombardment, and armored vehicles were implemented as well as various configurations of wireless apparatus, including mobile field radios which proved superior to telegraph and telephones at every level of command. Trench facing trench, the adversaries soon came to a stalemate. The war was not only fought in Europe. The Germans initiated a series of battles and guerrilla actions in East and Central Africa, including Lakes Tanganyika and Victoria, and several ports. The German intent was to divert Allied forces and supplies from Europe to Africa. Native troops were thusly recruited as shown in Fig. 17 and Fig. 18.

On the Allied side, nearly 400,000 Allied colonial soldiers and support personnel, and 600,000 African bearers pursued the much smaller but agile and elusive German force. This action was not successful—little resource was denied to the European campaign. This all ceased just prior to the 1918 armistice.

The transatlantic super stations progressively upgraded to the use of the contemporary leading edge transmitting modes: from spark to alternator to continuous wave. A contemporary antenna at Nauen is shown in Fig. 19.

Fig. 17. Single native troop. (By Bundesarchiv, Bild 105-DOA6369 / Walther Dobbertin / CC-BY-SA 3.0, CC BY-SA 3.0 de, https://commons.wikimedia.org/w/index.php?curid=5482344)

Fig. 18. Native troops on the march. (https://awayfromthewesternfront.org/campaigns/broader-themes/colonialism/)

Fig. 19. Ultra-modern Nauen antenna. (https://en.wikipedia.org/wiki/Nauen_Transmitter_Station#/media/File:Sendeanlage_Nauen)

The French Station

France did not have an official national wireless station. They did have a modest wireless station underground at the Eiffel Tower.[7] The tower, built in 1889, was 984 feet tall, and supported antennas which were capable of transmitting to the United States.[8] Most importantly, under the control of the army from 1909 onward, it was capable of listening in on enemy radio transmissions, providing critical guidance to its field army.[9] The Eiffel Tower antenna is shown in Fig. 20, and the radio station there is shown in Fig. 21. The Eiffel Tower radio station was sensitive enough to receive radio signals even from field stations, such as the one shown in Fig. 22.

Fig. 20. Eiffel Tower antenna. (https://www.researchgate.net/figure/Alberto-Santos-Dumonts-lightweight-steerable-airship-)

Fig. 21. Eiffel Tower radio station. (https://www.google.com/search?q=eiffel+tower+radio&sxsrf=ALeKk01EYOq9wrlP9LwKeYj_WJ7-gvM)

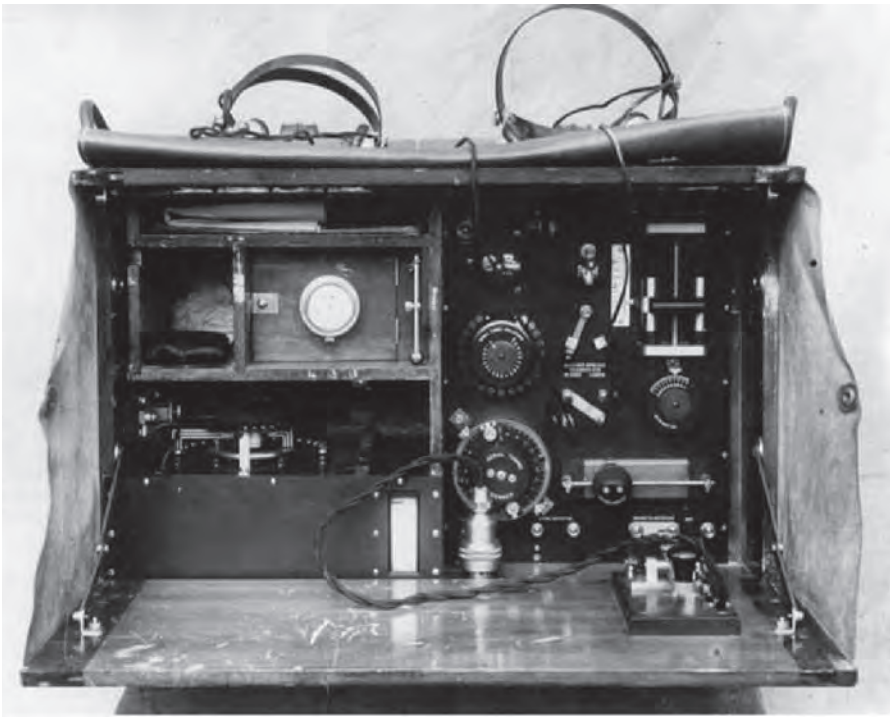

Fig. 22. Powerful WWI field radio. (http://musickpointradio.org/auckland-radio-zld/1912-1919/world-war-1-field-radios/)

Wartime Role of the United States

As reported, war developed in Europe in the latter part of 1914, and a number of powerful spark gap wireless stations in the United States worked with their sister stations in Europe. The stations provided the essential and sometimes critical communication of messages and press to and from stations abroad, particularly in Europe, and ships at sea. These stations were all owned by foreign entities, and their operations were of great concern to the U.S. government, which had adopted a policy of strict neutrality. By executive order on September 5, 1914, President Woodrow Wilson mandated the U.S. Navy Department regulate the activities of all radio stations. The Naval Radio Service took steps to minimize the possibility of these stations handling any traffic that could compromise the neutrality of the United States.

The navy moved quickly to disseminate the conditions of the executive order to all interested parties and to establish enforcement procedures. The stations were confronted with onsite monitoring of activities and the threat of silencing for any detected infractions. The navy, at the time, was the principal United States user of radio with extensive ship and coastal facilities. This new authority fulfilled the navy's ambition to control all radio transmissions emanating

in the United States within a military structure.

The surveillance of the dominating foreign owned commercial radio stations within the jurisdiction of the United States was a priority undertaking. Navy censors were stationed at the German stations (West Sayville, Long Island, New York, and Tuckerton, New Jersey) and the American Marconi stations (Siasconsett, Nantucket, South Wellfleet, Massachusetts, and New Brunswick, New Jersey). After initial protests, all operators eventually accepted the stringent regulations.

On April 7, 1917 the United States entered the war, and by way of executive order, the navy began the process of establishing radio as a government monopoly and ultimately American radio supremacy. All commercial as well as amateur use of radio was banned. The navy literally ruled the airwaves and was determined to have all radio and international communications fully under U.S. government domination.

This entry into the war brought with it additional demands for communications between the United States and Europe. The already overloaded undersea cable facilities were severely pressed to accommodate the added wartime vital traffic. The allies recognized the vulnerability of the allied cable system to submarine attack. Also, the five direct cables linking Germany to the Americas had been cut by Britain early in the war. Radio was called upon to provide a communications alternative and to relieve the traffic burden, particularly on the westbound leg.

One previously commercial radio operation became the focus of the effort to improve overall message capacity. The American Marconi station at New Brunswick, New Jersey, completed in 1914, was confiscated by the navy upon the United States entry into the war. The station, using the navy call sign NFF, was linked to MUU, the Marconi station at Caernarfon, Wales, which was under British government control. Inauguration of the Marconi station NFF is shown in Fig. 23. The Marconi station MUU at Wales is shown in Fig. 24.

These two stations became the principal transatlantic wartime communications link used by the Allies. The transmitters and transmitting antennas were more than adequate to get the signals across the Atlantic. MUU employed a 400 kW transmitter and an antenna mounted on ten masts, each 123 meters (400 feet) tall on a mountaintop. NFF maintained a wire antenna of 1.5 km (5,000 feet) length, supported by eight masts, each 123 meters (400 feet) tall powered by a 350 kW spark and, later in the war, a revolutionary Alexanderson 200 kW alternator. Two views of the newer technology Alexanderson alternators are shown in Fig. 25 and Fig. 26.

Although the U.S. transmitting ability was adequate and certainly optimum for the era and its technology, receiving was another matter. The received signals, particularly at the United States end, were sometimes weak, subject to fading and devastated by atmospheric noise. Reception was inconsistent and unreliable and had been so since the system's inception. The navy enlisted

Fig. 23. NFF Marconi inauguration, 1914. (https://www.semanticscholar.org/paper/Electrical-engineering-Hall-of-Fame%3A-Guglielmo-B)

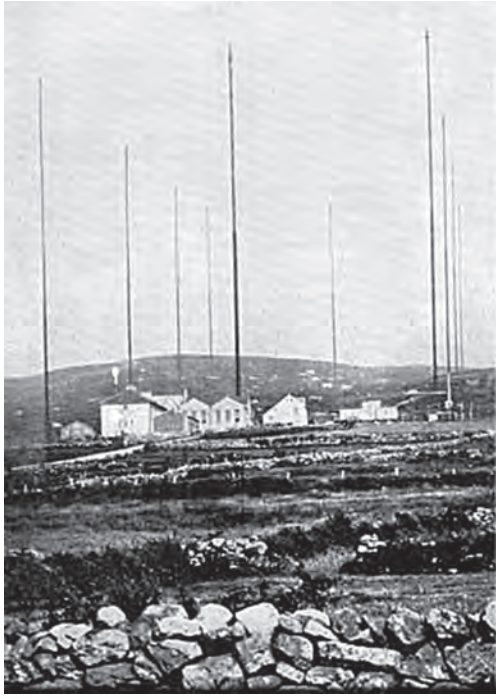

Fig. 24. MUU Marconi, Wales. (http://dave-mills.yolasite.com/early-wireless.php)

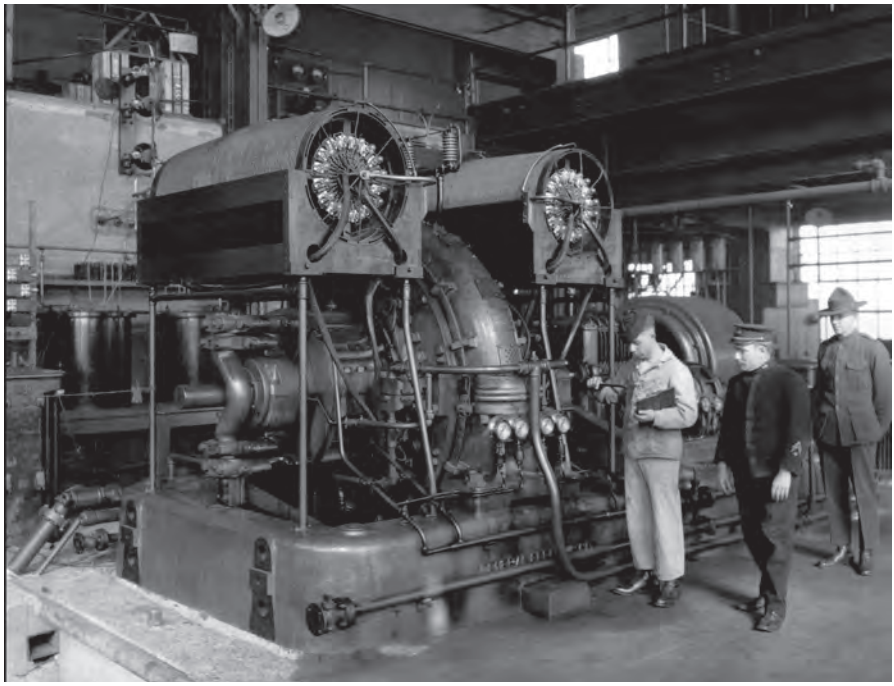

Fig. 25. Leap in technology–Alexanderson VLF Transmitter, view 1. (https://alexander.n.se/albert-einstein-the-alexanderson-high-frequency-alternator/?lang=en)

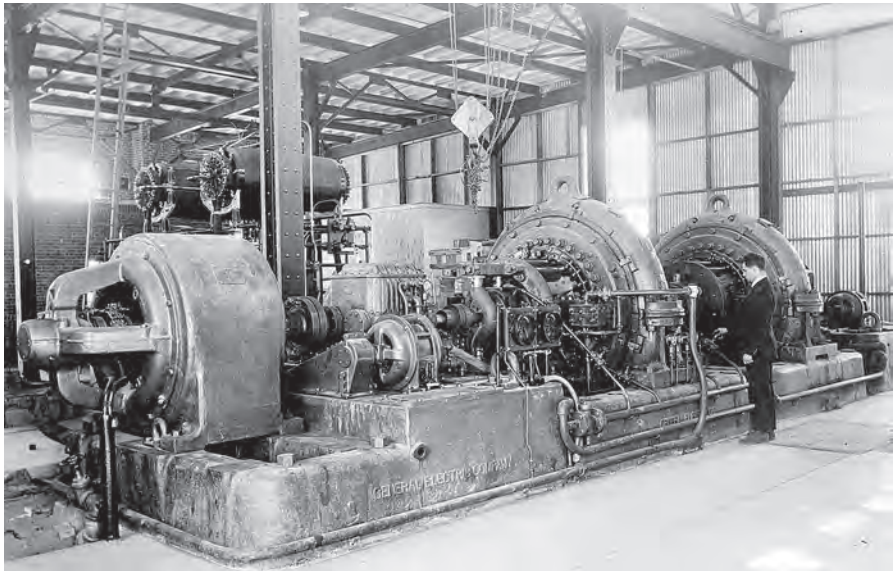

Fig. 26. Leap in technology–Alexanderson VLF transmitter, view 2. (http://www.theradiohistorian.org/transmitters/alternator3.jpg)

the assistance of staff and civilian scientists to design antenna systems that would lessen received noise, while others addressed the improvement of the receiving apparatus.

The new receiving facility, paired with the NFF transmitting facility, was located at Belmar, New Jersey, on a shallow inlet at the seacoast, 38 miles from New Brunswick. It was served by two remarkable antenna systems. The original installation was a bronze wire one mile long suspended on six masts, each 123 meters (400 feet) tall with three balancing towers, each 46 meters (150 feet) tall. In an effort to improve reception, the navy installed a newly conceived antenna system design comprising submerged underwater and underground collecting branches radiating from the operating building on a line bearing to Europe. Reception was improved, but uninterrupted copy was not obtainable. The signals collected at Belmar were augmented by those received at the confiscated German stations (WSL, Sayville, New York, and WCI, Tuckerton, New Jersey) and later, the Marconi station WCC at Chatham, Massachusetts, which had installed an underground antenna system similar to that at Belmar. The receiving stations were linked by leased telegraph landline to Radio Central at the Navy Yard in Washington.

Conclusion: War Had Little Benefit to the Countries

This war produced little benefit to any country and surely could not justify the enormous loss of life. The Great War brought an abrupt stop of Imperialism and changed the maps of the world forever. One of the few benefits to mankind was the evolvement of wireless. Wireless grew enormously during the late war years and the years immediately following. Technical advances brought on the "Golden Age" which saw the advent of global communications and the voice of broadcast radio that touched millions.

(Manufacturing engineering also benefited by the development of factory methods of producing weapons large and small in quantity, rapidly. Specifically, the technology to produce planes and tanks.)

ADDENDUM

Prelude to Armageddon: Wireless Super Stations and Imperialism

Fabbri's Silence—prelude To peace—Amateurs At War

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As the year 1917 dawned, the United States still struggled to stay out of the war in Europe. The international cable and wireless news services brought unfamiliar names to the fore: Liege, Lorraine, Ardennes, Ypres, Somme, and too many other successive sites of battles, which dominated the press. U-boat activity, the sinking of the *Lusitania,* and the German resumption of unrestricted submarine warfare antagonized the United States pacifists. On April 6, 1917, the United States declared war on Germany and began to go to the aid of their entrenched and exhausted British and French friends. This action overwhelmed the already overburdened cable capacity and put priority on improving transatlantic wireless reliability, which had been plagued by poor reception. Radios were used in the British trenches, shown in Fig. 27.

As the fighting intensified and German resolve firmed, many in the United States had recognized the inevitability of the United States entering the engagement on a limited or unlimited basis. Among these were the leaders of the

Fig. 27. The British trenches. (Almay stock)

American Radio Relay League, which encouraged its 3,000 members to be prepared. Once the declaration took affect, editorials in the newly founded League journal *QST* urged qualified amateurs to volunteer their desperately needed skilled services to the military. Enlistees were particularly directed to the navy, the nation's principal service user of wireless. A specific program was evolved to induct volunteer amateurs into the Naval Reserve for the duration. Appealing to the amateurs, the navy created the Class 4, Naval Reserve. The requirements for enrollment were citizenship, passing of a physical examination, and the ability to send and receive code at a rate of 10 words per minute. Active duty was compulsory during time of war. Most volunteering amateurs chose to join this reserve and served in the newly created Naval Communications Service. One such person was ARRL's first communications manager Fred H. Schnell, 1MO, who went to sea as a chief radioman. However, not all joined the Naval Reserve. Some enlisted in the army, such as ARRL cofounder Clarence D. Tuska, who opted to apply for, and received a commission as a lieutenant in the U.S. Army Signal Corps. He established a radio training school at the Ellington Airfield near Houston, Texas.

Our narrative concerns Alessandro Fabbri, 1AJ, and the reservist sailors who served under him at the Otter Cliffs Naval Radio Facility, many of whom were amateurs who had heeded the call to arms. Fabbri can be seen in Fig. 28 with other officers during a station commissioning, and a solo picture in Fig. 29.

As the navy receiving equipment and antennas began to be utilized, the significance of the stations' role began to become apparent. The United States had formally entered the war on April 6, 1917, a war like no other previously with two principal theatres—on land and at sea. The European land conflict required the infusion of U.S. troops and their equipment to break the stalemate and tip the scales in favor of the allies. The navy was responsible for transporting the more than a million-man U.S. Expeditionary Force safely to the battlefields of France and to protect the shipping supply lines. To accomplish this, the navy had to traverse the second war theatre—the Atlantic Ocean. Since 1914, the German U-boat fleet had ravaged shipping on the seas. From 1914 through 1916 the predators had sunk over 3,950,000 tons of shipping with torpedoes and mines. In the year the United States entered the war, the Germans sank 6,235,900 tons of shipping alone, some in U.S. coastal waters, and threatened to mine U.S. harbors. In the month of the United States entry, the approximately 140 submarines in the U-boat force sank a record 881,000 tons of vessels. The British Navy was sorely pressed, having lost over 140 warships of all classes up to the time of the United States entry.

The naval station NBD at Otter Cliffs, Maine, became a powerful weapon in these battles. Station NBD could, with exceptional clarity, hear the ALLO radio distress calls sent by vessels in the Atlantic when other navy east coast reception centers could not. ALLO, followed by the name of the vessel and

Fig. 28. Commissioning of station–August 28, 1917. In Whites: Chief Raymond Cole, Ensign Alessandro Fabbri, and unknown Officer. (https://www.navalhistory.org/2010/08/28/commissioning-the-otter-cliffs-radio-station-28-august-1917)

Fig. 29. Lieutenant Alessandro Fabbri, 1919. (US Naval Historical Center (MOD 5635))

its position, was the distress call used by vessels under submarine attack or reporting a U-boat sighting. These calls were numerous, and the information was wired to Washington from where necessary alerts and orders were dispatched. The navy also operated numerous commercial wireless stations, which had been commandeered. NBD was also capable of monitoring coded German U-boat signals. The German naval code was known to the British early in the war, and was likely used by the Washington receptors to decipher the messages relayed by NBD. There were some happy times when an enemy ship was sunk, as shown in Fig. 30. For all the happy times when an enemy ship was sunk, there were unhappy times when you were on the receiving end, and the ship sunk was yours, as shown in Fig. 31.

The daily NBD station routine was perfected to the extent that virtually uninterrupted reception of the traffic from MUU in Caernarfon, Wales, from IDO in Rome, Italy, and from YN in Lyons, France, was achieved. These European stations were copied consistently when no other U.S. east coast station could do so reliably. These exceptional results were achieved by expert, disciplined radio monitors at dedicated desks utilizing leading edge receivers fed signals from the sensitive antenna systems tuned to the particular station assigned. The radio receiving room at one point in time at Otter Cliffs is shown in Fig. 32.

Fig. 30. Happy soldiers on a ship. (https://www.alamy.com/stock-photo/troop-ship.html)

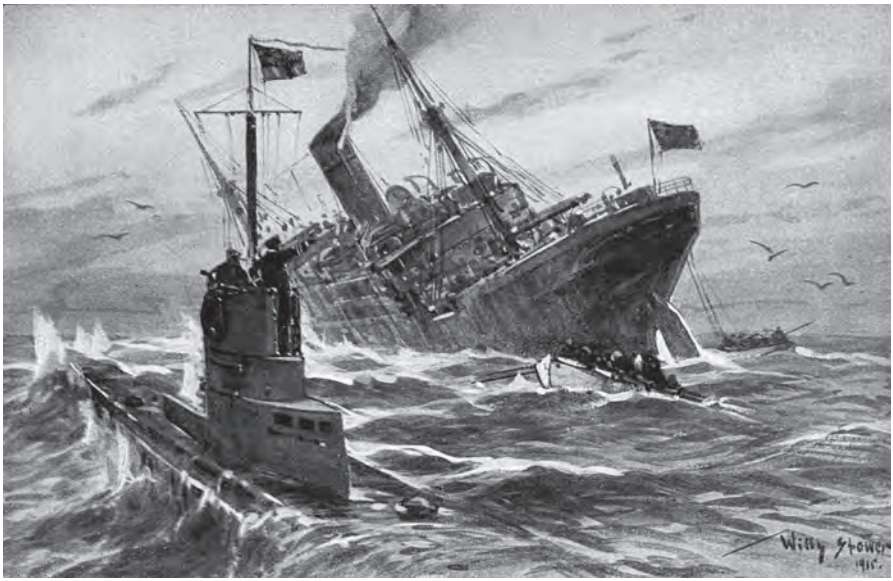

Fig. 31. Artist depiction of torpedoed troop carrier. Actually the United States lost no troop ships. Lost were four war ships and six merchantmen. These from the total of 5,000 vessels lost during the war. (https://www.google.com/search?q=UBOAT+TORPEDO+TROOP+SHIP&tbm=isch&ved=2ahUKEwi5__jk9O7tAh)

This cross-Atlantic traffic was all coded and sent only once. The volume was so heavy that there was no time for repeats or fills; the messages had to be copied correctly the first time, attesting to the ability of the operators. Lieutenant Fabbri reported receiving as many as 28,000 words in one day and a record 54,000 words in 48 hours, including 1,003 messages. As the war operations unfolded, radio YN at Lyons, France, became the principal message traffic terminal for the AEF in France. NBD eventually was receiving 24 hours a day continuously with 100% reception. The messages were relayed to Washington, DC, by landline. Washington traffic and responses were transmitted to Europe by NFF, the former Marconi station at New Brunswick, New Jersey, and NAA, the Naval radio station at Arlington, Virginia.

The one kilowatt transmitter at NBD was rarely used to avoid interfering with reception operations, except on December 7, 1917, when the station was in contact with radio VCS in Halifax, Nova Scotia. The city had been devastated by an enormous munitions explosion in the harbor and was badly in need of assistance. NBD in turn contacted the Boston Navy Yard, from where the hospital ship USHS *Comfort* sailed to the relief of the city.

Significantly, on October 6, 1918, NBD copied an announcement transmitted in English, in the open, by radio POZ, the principal German station near Berlin. President Woodrow Wilson was

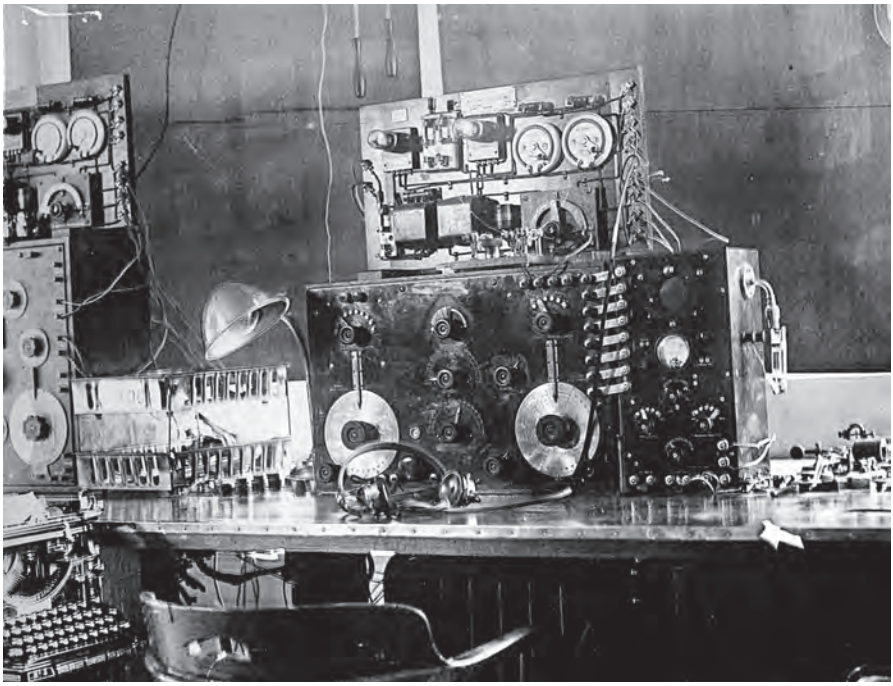

Fig. 32. One of the Trans-Atlantic long wave receiving positions at Otter Cliffs. (Photo courtesy Jesup Memorial Library, https://www.navycthistory.com/ottercliffs01.html).

requested to participate in peace negotiations to lead to a general armistice on land, sea, and in the air. The armistice talks were soon engaged and the armistice became effective at the eleventh hour, of the eleventh day, of the eleventh month of 1918.

But the role of NBD was far from concluded. With deactivation and troop transports returning from Europe, the travels of the president and the meetings at Versailles, the station was busier than ever, with the total station complement reaching 180 men. Fig. 33 shows Fabbri and his peacetime crew. Fabbri and his crew used the Bar Harbor Country Club (Fig. 34) for NBD control and as a receiver station.

And the station was given a loud voice. A five kilowatt selectable arc or spark gap transmitter arrangement was located remotely at Seawall, Maine, six miles southwest of the Otter Cliffs facility and connected by a submarine cable. Antenna science had advanced somewhat and the station was enhanced by a 400 foot flat top antenna supported between two 220 foot guyed wooden towers with an extensive ground system partially under the ocean, producing remarkable signals to the North Atlantic and Europe. The transmitting/receiving combination became operational immediately following the armistice in time to be commended for providing reliable two-way communications for

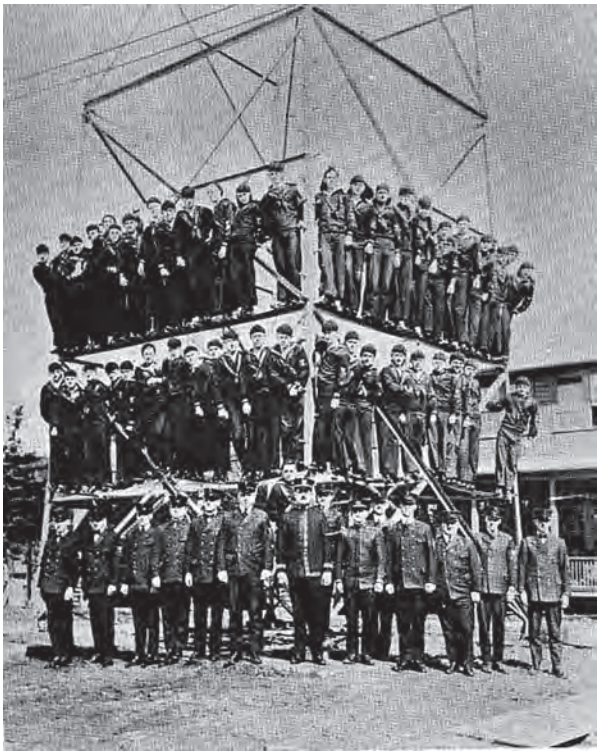

Fig. 33. Alessandro Fabbri & crew, 1919. (https://www.google.com/search?q=alessandro+fabbri+maine&sxsrf=ALeKk00Vy8EuMQUVM_8N2Upe_KLVok9KyQ:1609098543381&source=lnms&tbm=isch&sa=X&ved=2ahUKEwjQp9iY9-7tAhUUGVkFHciFCn4Q_AUoAnoECAcQBA&biw=1600&bih=757#imgrc=wprJVXOlZNMdlM)

Fig. 34. The Bar Harbor Country Club building leased by Mr. Fabbri for use as NBD control and receiver station. (Photo courtesy Carl Herr, https://www.navycthistory.com/ottercliffs01.html)

President Woodrow Wilson and staff, who journeyed twice, back and forth, to Europe for peace talks. The party traveled aboard the U.S.S. *George Washington*, an interned German steamship that served as a troop transport. Amateur operator Fred H. Schnell, 1MO, future ARRL Traffic Manager, served as chief radioman aboard the U.S.S. *George Washington* during these transits.

As post war operations continued at Otter Cliffs, the reservists were gradually deactivated and replaced by regular navy enlisted personnel. Activity continued at a great pace as successive numbers of east coast major naval stations were secured in favor of the unique capabilities of NBD.

On Armistice Day, November 11, 1920, President Wilson awarded Lieutenant Alessandro Fabbri, now 1VX, the Navy Cross, shown in Fig. 35. The commendation reads in part…"For exceptionally meritorious service in a duty of great responsibility in the development of the radio receiving station at Otter Cliffs, Maine, and the small receiving station at Sea Wall. Under Lieutenant Fabbri's direction, the station was developed from a small, amateur experimental station until at the end of the war it was the most important and the most efficient station in the world." Josephus Daniels, Secretary of the Navy, signed it for President Wilson.

Fabbri, who had returned to private life at the end of 1919, shared the award with his crew. He became a silent key prematurely due to pneumonia at age 44, on February 6, 1922.

Having outlived their usefulness, the Otter Cliffs and Seawall installations were disassembled and demolished in 1935. The only surviving structure is the lookout tower, which housed the radio direction finder facility. This lighthouse shaped building was relocated to nearby Moose Island.

Fig. 35. Fabbri's honor—Navy Cross—The U.S. Navy's second-highest military decoration awarded for exceptionally meritorious service. (https://www.medalsofamerica.com/navy-cross-medal)

The original NBD sites are enveloped in the Acadia National Park. This rocky, woodland park created in 1916 is 47,000 acres in size, and is located

mainly on Mount Desert Island. The NBD main site is circled by a park road, which intersects the Fabbri Monument Road leading to the Fabbri Memorial, inset in a large red granite boulder. The memorial plaque of Fig. 36, reproduced in Table 3 for easier reading, was created by the Bar Harbor townspeople in 1939 to commemorate the extraordinary accomplishments of their neighbor.

This is not the end, but the continuance of the devotion that amateur radio operators worldwide have extended to their countries in their times of peril. Keys at the ready, amateurs have continued to volunteer their skills in those conflicts, which succeeded the inaptly termed "War To End All Wars." Some fell as heroes and all should never, ever, be forgotten.

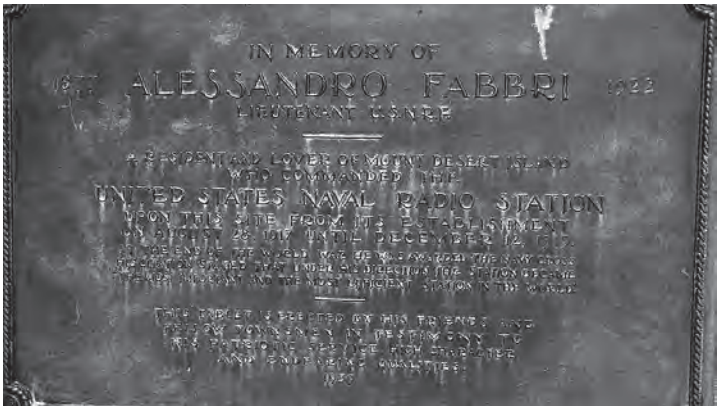

Fig. 36. Memorial plaque in dedication of his service. This can be found in Arcadia National Park west of the Fabbri Picnic Area, located off the Park Loop Road, Acadia, Maine. (National Park Service, U.S. Department of the Interior)

Table 3. Memorial to Alessandro Fabbri, transcribed for easier reading. (Author)

IN MEMORY OF 1877 ALESSANDRO FABBRI 1922 LIEUTENANT U.S.N.R.F.
A RESIDENT AND LOVER OF MOUNT DESERT ISLAND WHO COMMANDED THE UNITED STATES NAVAL RADIO STATION UPON THIS SITE FROM ITS ESTABLISHMENT ON AUGUST 28, 1917 UNTIL DECEMBER 12, 1919. AT THE END OF THE WORLD WAR HE WAS AWARDED THE NAVY CROSS. HIS CITATION STATED THAT UNDER HIS DIRECTION THE STATION BECAME "THE MOST IMPORTANT AND THE MOST EFFICIENT STATION IN THE WORLD."
THIS TABLET IS ERECTED BY HIS FRIENDS AND FELLOW TOWNSMEN IN TESTIMONY TO HIS PATRIOTIC SERVICE, HIGH CHARACTER AND ENDEARING QUALITIES. 1939

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About the Author

Michael W. Marinaro was born in Brooklyn, NY. He attended Erasmus Hall High School, Baruch School, and City College of New York, where he earned a BBA. Later, at Central Connecticut State University, he earned a MA in history with honors.

His managerial career finished with the position of vice president of industrial distribution and marketing management in the financial services industry. He is now retired. Michael is a veteran in the Army Reserve and was called into active duty during the Berlin crisis.

In amateur radio, he has been licensed continuously for sixty eight years. He is currently an extra class with call letters WN1M. Previously he held calls KN2CRH, K2CRH, W5RBB, and W1HNJ. Awards earned are DXCC and WAS.

Michael is the author of many historical wireless articles published in *QST, ARRL Journal, Practical Wireless,* and *Antique Wireless Association Journal.* He is a contributing editor and columnist at ARRL. He is a member of the American Radio Relay League, Collins Collectors Association, and *Marconista763.* As an AWA member, he has received writing awards for articles in the *AWA Journal*. He is the volunteer staff historian at the American Radio Relay League, the historian-archivist, and curator.

Oliver Lodge's Contribution to the Discovery of Electromagnetic Radiation

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Sir Oliver Lodge established a remarkable reputation during the last decade of the 19th century when the scientific community credited him with the development of lightning protectors, the discovery of electromagnetic radiation on wires, the discovery of the coherer principle, and the invention of radiotelegraphy. Lodge's claims for the discovery of the coherer principle were based on an experiment on lightning guards performed in 1889, and his claims for the invention of radiotelegraphy were based on a popular lecture entitled "The Work of Hertz" delivered at Oxford in October of 1894. Historians of the 20th century, mostly English, were exceedingly kind to Lodge in their accounts of his work. It has become increasingly clear in publications in the last 20 years that Lodge claimed credit for far more than he actually accomplished in the field of electricity during the last two decades of the 19th century. Two publications by this author have provided ample evidence that Lodge knowingly misrepresented the results of the experiments he used to support his claims for discovery of the coherer principle and the invention of the radiotelegraph. The intent of this paper is to document that Lodge also misrepresented the results of his "recoil kick" experiments performed in 1888, which he used to support his contention that he independently discovered the electromagnetic waves predicted by Maxwell at almost exactly the same time as Hertz discovered electromagnetic waves in free space. Oliver Lodge's misrepresentations of his "recoil kick" experiment, which is addressed here, represents the third in a trilogy of papers describing electrical experiments in which Lodge misrepresented the results of his experiments to make unwarranted claims of invention and discovery.

Introduction

Oliver Lodge (1851–1940) was a British physicist and inventor (see Fig. 1) who received widespread recognition for many accomplishments in the field of electricity during the last two decades of the 19th century. Lodge received a Bachelor of Science degree from the University of London in 1875 and a Doctor of Science degree in 1877. He was appointed professor of physics and mathematics at University College, Liverpool, in 1881, and served there during the period he gained recognition for his contributions. He then served as Principal of the University of Birmingham from 1900 to 1920, at which time he retired. He was a prolific writer, authoring more than 40 books and literally hundreds of publications in prestigious journals of the day. He received a number of awards in his lifetime; most notably, he was

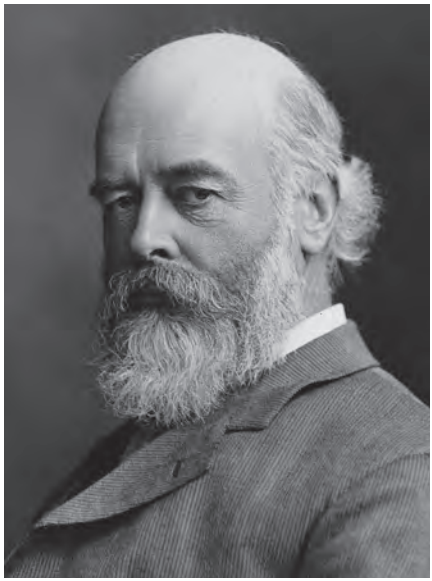


Fig. 1. Oliver Lodge was a British physicist and inventor who gained recognition for many accomplishments in the field of electricity during the last two decades of the 19th century. (Lafayette Ltd.)

elected a Fellow of the Royal Society of London (FRS) on June 9, 1887, and knighted by King Edward VII in 1902 for his many contributions to science and British industry. He was also awarded the prestigious Rumford Medal of the Royal Society in 1898, the Albert Medal in 1919, and the Faraday Medal in 1932.

Lodge has been credited with demonstrating the importance of self-inductance in designing lightning protection circuits and independently discovering the electromagnetic waves predicted by Maxwell in the form of standing waves on wires in 1888, discovering the coherer principle in 1889, and demonstrating the transmission and reception of telegraphic messages with Hertzian waves at a popular lecture entitled "The Works of Hertz" at Oxford in 1894. He also popularized the concept of syntony (tuning) and filed his first patent on sharp tuning in 1897 for use in radiotelegraph systems.

Despite his many honors and accomplishments, Lodge made increasingly expansive claims in his writings, lectures and his books later in life describing his contributions to the discovery of electromagnetic waves, the coherer principle, and the early transmission of telegraphic messages. Examples of relevant books published after his retirement in 1920 with increasingly expansive claims are *Talks about Wireless*, *Talks about Radio, Advancing Science*, and his autobiography, *Past Years*.[1] Many of these claims were either unsubstantiated or contradicted by earlier writings published by Lodge, and yet many historians, particularly his fellow countrymen, accepted Lodge's claims as fact with little or no scrutiny.

These claims have been scrutinized in more detail in recent years, and the discrepancies between Lodge's claims and the documentary evidence have come into sharper focus. Lodge's claims for the discovery of the coherer principle were discredited in a previous article in the *AWA Review* in 2015.[2] Lodge's claims for sending telegraphic messages in 1894 were rejected by Charles Süsskind in 1969,[3] by Sungook Hong in his book *Wireless, From Marconi's Black-Box to the Audion* published in 2001,[4] and by this author in an article published in 2013.[5] The 2013 article documented Lodge's candid admission in sworn testimony before the British Parliament that he did not send telegraphic messages at Oxford,[6]

and it also cited a previously unchronicled paper in which Lodge documented his Oxford lecture and clearly stated that he sent long and short signals in the context of a vision experiment—not in the context of sending telegraphic messages with Hertzian radiation.[7]

A common theme in Lodge's claims for discovering the coherer principle and the invention of a system of transmitting radiotelegraphic messages is that Lodge actually learned of the discovery of the coherer and the invention of the radiotelegraph through previous publications of the experiments made by two other individuals, and each of those experiments reminded Lodge of similar experiments that he had made earlier—similar enough so that he could claim he had made the same discovery first and independently. In both of these cited cases, the experiments he selected had nothing to do with the theme of the discovery. Lodge claimed that he had discovered the coherer principle in the course of a lightning experiment using high voltages that were inconsistent with the coherer principle, and he claimed he had transmitted telegraphic signals at Oxford during the course of a vision experiment that did not involve telegraphic signals.

The objective of this paper is to document the assertion that Lodge reinterpreted his "recoil kick" experiment to make it appear that he independently discovered electromagnetic waves on wires in an experiment that he disclosed to the Society of Arts in a demonstration lecture on the subject of lightning conductors on March 17, 1888. This lecture predated Hertz's publication in which he disclosed his discovery of electromagnetic waves in air, but it postdated Hertz's paper published on February 9, 1888, in which he disclosed the discovery of standing waves on wires. And in a postscript dated July 24, 1888, Lodge made his claim for the first time that he discovered ether waves by observing standing waves on wires due to resonances. However, this claim was made right after he read Hertz's paper revealing that he had discovered electromagnetic waves in air predicted by Maxwell by observing standing waves produced by reflections from a metal surface.

While it is generally accepted that Hertz was the first to discover electromagnetic waves in air predicted by Maxwell, Lodge and many other historians claim to this day that Lodge also discovered electromagnetic waves independently and at about the same time as Hertz. For example, noted historian Hugh Aitken allowed that Hertz had "anticipated" Lodge in the discovery of electromagnetic waves, but he quickly followed that by stating: "Lodge's experimental verification of Maxwell's equations had been carried out at almost exactly the same time as Hertz's and was, in principle, no less conclusive."[8] In another example, historian James P. Rybak wrote an article for the *AWA Journal* about Oliver Lodge's work with electromagnetic radiation in which he claimed, "In addition to demonstrating the effects of inductance in circuits with time-varying currents, the experiments ultimately resulted in Lodge establishing the existence of electromagnetic waves independently of, but

virtually simultaneously with, the German scientist Heinrich Hertz."[9]

Another notable Lodge historian, Peter Rowlands, went one step further and recently claimed that Lodge actually had priority over Hertz in the discovery of electromagnetic waves, but was not properly recognized:

> "Further experiments after the lectures [Mann lectures by Lodge in March 1888] led to many incidental discoveries, another lecture-demonstration to the Physical Society at South Kensington in May, and publication of the early results in June. These included the first actual publication of any verification of Maxwell's theory and the first published statement that electromagnetic waves had been discovered, with the correct wavelengths if their velocity was assumed to be that of light, as Maxwell's theory required. Lodge's priority in this has been consistently overlooked, partly because he himself gave the impression that he had been forestalled by Hertz in his later *Philosophical Magazine* article of August 1888, and partly because the Society of Arts publication of June was omitted from his official bibliography."[10]

It will be shown that Lodge was well aware of Hertz's work on the discovery of standing waves on wires before Lodge ever published his first paper on his experiments addressing this topic. It will also be shown that Hertz published all of the results of his discovery of standing waves on both wires and in free space before Lodge published any papers describing his experiments. Finally, it will be shown that the standing waves on wires that Lodge claimed he discovered were not the same as the propagating waves in free space that James Clerk Maxwell predicted.

The account of Lodge's claims for the discovery of electromagnetic waves in this paper is a cautionary tale on two levels. First, it documents many deceptions and false statements by a respected scientist with an outstanding reputation who attempted to gain recognition for a very important discovery. Second, it suggests that a number of historians were complicit in these deceptions by accepting and publishing Lodge's claims as fact with little or no proof, and by failing to scrutinize the technical details of the experiments he cited. It is likely that Lodge's claims were not challenged at the time in part because of his reputation and in part because the technology was not well understood by many of his colleagues and contemporaries. This seemingly harsh assertion about historians will be substantiated by documenting examples of how noted historians were so easily deceived by Lodge's descriptions of how he discovered electromagnetic waves.

Lodge's Contributions to the Discovery of Electromagnetic Radiation

The Maxwellians

Oliver Lodge was one of a group of scientists in the U.K., known as the Maxwellians, who became interested in James Clerk Maxwell's 1873 publication, *Treatise on Electricity and Magnetism*.[11] At the time of Maxwell's death in 1879,

his work had interested only a few scientists in the U.K. and even fewer on the Continent (Europe) and in America. The Maxwellians, most notably George F. FitzGerald in Ireland, Oliver Heaviside, and Oliver Lodge in England—and somewhat later, Heinrich Hertz in Germany—took it upon themselves to clarify Maxwell's theory, test its predictions, and convert its formalism into one that eventually was universally adopted.[12] Heaviside was responsible for naming the group the Maxwellians, and Professor FitzGerald was its titular leader.

The Maxwellians believed in the existence of propagating electromagnetic waves in free space that Maxwell had predicted in his treatise, and they also believed the speed of currents in electrical circuits and waves in free space was equal to the speed of light. Unlike the speed of electrical waves, the speed of light had already been determined experimentally because light was abundant in the natural environment and it was relatively easy to detect by the eye at the long distances of separation needed for direct measurements.[13] The speed of currents in circuits and electromagnetic waves propagating in free space was another matter. Direct measurement of the speed of currents in circuits was difficult because of the small dimensions of electrical circuits and the apparent high speed of currents. Detection of propagating electromagnetic waves in free space with frequencies in the range of what is now known as radio frequencies was difficult because methods of both generating and detecting high-frequency electromagnetic waves were unknown.

The Controversy over the Theory of Electricity

Maxwell's theories were not universally accepted at the time he wrote his treatise, so the challenge for the Maxwellians was to verify the predictions of Maxwell by demonstrating 1) the speed of currents in circuits was finite and equal to the speed of light, 2) the existence of propagating electromagnetic radiation in free space, and 3) that electromagnetic waves displayed the same properties as light—for example, rectilinear propagation, polarization, reflection, and refraction.

At the time Maxwell published his treatise, there were several other schools of thought regarding the theory of electricity and magnetism.[14] One of the more prominent ones was the "action-at-a-distance" school based on Newtonian mechanics, led by André-Marie Ampère, Franz Neumann, and Wilhelm Weber, who theorized the speed of currents on wires was essentially infinite and that electromagnetic waves in space did not exist.[15] It may be difficult for today's scientists and engineers to comprehend how scientists of that day could have believed that electric and magnetic fields, and the associated forces they produced at a distance, were instantaneous. However, the existing laws of electricity and magnetism at the time (e.g., Faraday's Law, Ampere's Law, Coulomb's Law, Kirchhoff's Law) were based on experimental observations that electric fields decreased as the square of distance from a point charge, and fields from electric dipoles and closed loops decreased as the cube of distance. Thus, a delay in electric and magnetic fields at the longest measurable

distances from the known sources of electricity could not be detected—especially from sources with high frequencies.

The problem of detecting electromagnetic radiation in free space was even more daunting. Before the experiments of Hertz, there was no known way to generate or detect electromagnetic waves in free space. Also, the electrostatic fields needed to produce the radiated electromagnetic fields dominated the propagating electromagnetic radiation to a distance equal to approximately one-sixth of the wavelength from the source. (The electrostatic and electromagnetic fields from a dipole radiator are equal at a distance of approximately one-sixth of a wavelength). To observe propagating electromagnetic fields in free space within a laboratory would have required sources that radiated energy with wavelengths of less than 10 meters in order to be in the far field where the radiating fields dominated electrostatic fields. Again, there was no known way of generating such short electromagnetic waves before the experiments of Hertz published in 1887.

Objectives of the Maxwellians

The Maxwellians were looking for experimental confirmation of Maxwell's equations and theories that would put an end to the controversy. For a period of 14 years following the publication of Maxwell's treatise in 1873, the Maxwellians in the U.K. had been trying to determine how to generate and detect the electromagnetic radiation in free space predicted by Maxwell and his equations. Lodge and FitzGerald had many discussions on how the radiation predicted by Maxwell could be generated. In 1883, FitzGerald suggested that the predicted radiation might be generated by a spark produced by the discharge of an accumulator (e.g., a Leyden jar) and the subsequent oscillatory discharge current that followed, a suggestion that he documented in an article appropriately entitled "On a Method of Producing Electromagnetic Disturbances of Comparatively Short Wave-lengths." This entire paper, referring to the title, consisted of two sentences: "This is by utilizing the alternating currents produced when an accumulator [capacitor] is discharged through a small resistance. It would be possible to produce waves of as little as ten metres wave-length, or even less."[16] Lodge was sufficiently impressed by this statement that he reproduced it in his autobiography.[17]

FitzGerald's suggestion to look for waves produced by spark discharges eventually proved to be correct, but Lodge and FitzGerald were unable to capitalize on it. They continued to have discussions on how to generate and detect electromagnetic radiation that Maxwell had predicted, but they made little progress in actually generating or detecting electromagnetic radiation in free space. Hertz began his experiments in late 1886 that led to his discovery of the electromagnetic waves in air in March of 1888 by Hertz, the results of which he published on May 20, 1888.

Lodge's search for the electromagnetic radiation predicted by Maxwell began shortly after Maxwell published his treatise in 1873, but he did not make

any real progress in that direction until the year 1888 when he became interested in lightning conductors and methods of protecting buildings and electrical equipment from lightning strikes. Lodge claimed that the experiments he performed in early 1888 simulating the response of lightning conductors and lightning protection equipment led him to his discovery of standing waves on wires, which he claimed were the same as the electromagnetic waves predicted by Maxwell.

The basic thesis of this paper is that Lodge did not discover or observe standing waves on wires in his lightning experiments in 1888. Instead, Lodge read about Hertz's discovery of standing waves on wires after he performed his lightning experiments in March 1888 but before he documented those experiments in the *Journal of the Society of Arts* later that year. A case is made that he reinterpreted the data of his lightning experiment based on his reading of Hertz's results before he published his first paper on this subject on June 22, 1888, in which he claimed that he had observed standing waves in his March 1888 tests. This may sound suspiciously like a conspiracy theory, but the documents and facts presented here fully support this thesis.

Paper Organization

The narrative begins with Lodge's lectures on lightning conductors, known as the Mann lectures, which Lodge presented to the Society of Arts in two lectures on March 17 and 24, 1888. Most of Lodge's work with standing waves on wires occurred in 1888, although there were certain events and lectures that occurred as late as 1891 that are described here. In particular, Lodge rewrote the history of his participation in the discovery of electromagnetic waves in a presentation to the Royal Society on June 4, 1891. He affirmed the revised history of his participation in his autobiography published in 1931, portions of which are cited in the narrative as appropriate. The narrative of this paper is organized in seven sections with the following titles:

- Lodge Presented his Lightning Conductor Experiments (March 17, 1888)
- Lodge Had Prior Knowledge of Hertz's Work on Standing Waves (June 22, 1888)
- Lodge Documented his Recoil Kick Experiment (June 22, 1888)
- Lodge Proposed an Application for his Recoil Kick Experiment (July 7, 1888)
- Lodge Claimed he Discovered Ether Waves Predicted by Maxwell (July 24, 1888)
- Lodge Disclosed His Discovery of Ether Waves to the British Association (September 1888)
- Lodge Rewrote the History of his Discovery of Ether Waves (June 4, 1891)

Lodge Presented his Lightning Conductor Experiments (March 17, 1888)

In late 1887, Lodge received an invitation by Sir Henry Trueman Wood, Secretary of the Society of Arts, to deliver a lecture in memory of the late Dr. Robert

Mann, who was an enthusiastic advocate of lightning rods in South Africa. Lodge immediately became enamored with the subject of lightning conductors and protectors, and he claimed that he began to experiment with the discharge of Leyden jars in February 1888 to simulate the response of lightning protection apparatus produced by lightning strokes. His early experiments were named the "alternative path," which he said began in February 1888, and the "recoil kick," which he said began on March 1, 1888.[18] Lodge presented preliminary results of his work to the Society of Arts in two lectures entitled "Protection of Buildings from Lightning," the first being an introductory lecture on March 10, 1888,[19] and the second being a demonstration lecture featuring experiments with high-voltage discharges from Leyden jars designed to simulate the effect of lightning responses presented on March 17, 1888.[20] The experiments of the alternative path and recoil kick were included in the second lecture.

In the documentation of his second lecture, he stated, "I want to show that conductivity is, from many points of view, of hardly any moment, and that the circumstances of a discharge are regulated far more by inertia [inductance] than by conductivity."[21] Lodge's basic thesis was that at the high-frequency content of lightning, which he believed to be in the range of 0.1 to 1 MHz,[22] the inductance of a wire was more important to the response of a lightning protection system than its DC resistance. While Lodge was correct about this point, it was not necessarily the view of many electrical engineers of the day who were more familiar with low frequency currents and who believed the conductivity of the wires was a more important factor.

Lodge realized he was going to face stiff opposition from old-guard engineers, many of whom at that time had little or no knowledge of inductive impedance, so he designed a series of experiments on various wire configurations characteristic of lightning protection circuits that would produce responses, when excited by high voltages and high frequencies, that were substantially different from responses that would be expected by those who had no experience with high voltages and frequencies. Lodge's favorite experiment, the alternative path, was the discharge of Leyden jars that were initially charged to high voltages into a circuit with two alternative paths—a long wire with a very low DC resistance and a short air gap with an extremely high DC resistance (see Fig. 2). The long wire path had a low DC resistance but a very high AC impedance at a megahertz, which produced a very large voltage drop capable of breaking down the high-resistance air gap, thereby converting the air gap into a low impedance path. Lodge was able to demonstrate that lightning often preferred to jump from the wires of lightning protection systems to the structure itself because of the high impedance of the wire. The experiment of the alternative path was very popular with the audience and was described in several electrical journals of the day immediately after the lecture.[23]

The experiment of the alternative path led directly to the experiment of

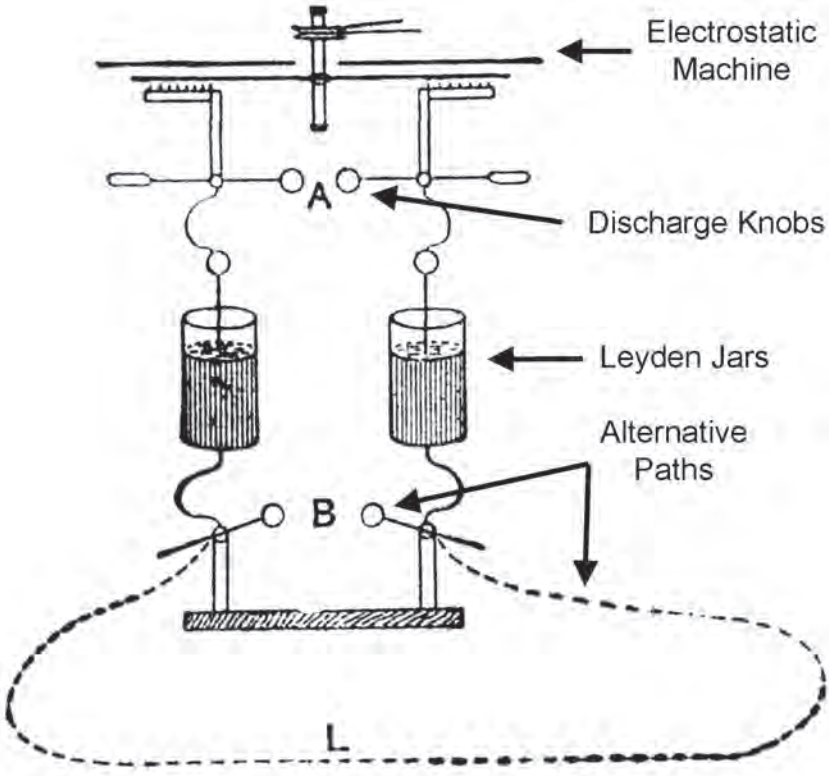


Fig. 2. The experiment of the "alternative path" provided two possible paths for the flow of current generated by the high voltages produced by an electrostatic machine when applied to two alternative paths: a long low-resistance copper wire L and a high-resistance air gap B. (*J. Soc. Arts*, Vol. 36, p. 880)

the recoil kick, in which a series of Leyden jar discharges were applied to two long parallel wires that formed an open-circuited transmission line. Lodge found that the voltage at the open end of the line would double due to the reflection of the applied voltage at the unterminated end of the line, which he called the recoil kick. Lodge would later claim that the standing waves he observed on the transmission line of the recoil kick experiment were the electromagnetic waves predicted by Maxwell.

The experiment of the recoil kick will be the focus of the remainder of this article, which Lodge documented for the very first time in a paper that appeared in an issue of the *Journal of the Society of Arts* dated June 22, 1888. Before introducing the recoil kick experiment, it is important to point out that in Lodge's first paper he documented the fact that he had read Hertz's early work published in 1887 describing his discovery of standing waves on wires caused by resonances with his dipole oscillator. The fact that Lodge

had not completed the documentation of his recoil kick experiment before he read Hertz's work on his discovery of standing waves is a critical factor in evaluating Lodge's later claim that he *independently discovered* standing waves on wires, much less the electromagnetic waves predicted by Maxwell.

Lodge had Prior Knowledge of Hertz's Work on Standing Waves (June 22, 1888)

It is generally believed that Lodge and Hertz were unaware of each other's work on standing waves until after Hertz's discovery of electromagnetic waves in air was made known in the U.K. circa late June or early July 1888. This belief resulted from several statements such as this one recorded by Lodge:

> "In 1888 I succeeded in making a rough preliminary determination on this very plan; but avoided the necessity for excessive lengths of wire, by using the principle of reflection and interference to obtain stationary waves in a pair of parallel wires of known length attached as lateral appendages to a Leyden jar circuit: such waves being excited at every discharge.… Experiments on these stationary waves in wires, observation of their nodes and loops, and measurements of their wavelength, were going on at Liverpool, simultaneously with, but *independently* [emphasis added] of, the experiments of Hertz in Carlsruhe [sic] on waves in space."[24]

Lodge's statements of independence were reinforced by language appearing in more formal documents, such as this one prepared on Professor Lodge's behalf at the time he was awarded the Rumford Medal in 1898:

> "In dealing with the history of the discovery by Professor Hertz of electro-magnetic radiation, it would be impossible to pass over the work done previously, or simultaneously, by Professor Lodge, on the surging or oscillatory character of the transmission of electric discharges along wires. Professor Lodge gave an account of his observations in his lectures to the Society of Arts, delivered in 1888, which are incorporated in the treatise on 'Lightning Conductors and Lightning Guards,' published in 1892. *The researches of the English and German physicists were entirely independent* [emphasis added], and, though the merit of the actual discovery of electromagnetic radiation certainly belongs to Professor Hertz, there seems to be little reason to doubt that Professor Lodge's experiments would have led him eventually to the same result."[25]

The assertion here is not that Lodge was influenced by Hertz when he designed and performed the recoil kick experiment in March 1888. The assertion is that he read Hertz's work before he completed the documentation of the very first manuscript describing his work with waves on wires. The real issue is, "How much did Lodge reinterpret the data he obtained in March 1888 based on his reading of Hertz's work during the time he prepared his paper for publication in

June 1888?" A related question is, "What other documents might Lodge have read that Hertz published between May 1887 and the time Lodge's paper was submitted for publication in early June 1888?"

What Lodge Would have Learned by Reading Hertz's May 1887 Paper

Despite Lodge's many claims that his work was independent of Hertz, he disclosed in the issue of the *Journal of the Society of Arts* dated June 22, 1888, that he had read Hertz's early publication dating to May 15, 1887, which detailed Hertz's discovery of standing waves on wires produced by resonances excited by the short waves produced by the new spark-driven dipole oscillator he had just invented. The evidence that Lodge read Hertz's papers from 1887 is in the form of this footnote that appeared on the last page of Lodge's paper in the *Journal of the Society of Arts* [emphasis added]:

> "At the second lecture [March 17, 1888] I learnt that some experiments on lightning protectors… had been made previously by Professor Hughes and M. Guillemin (address to telegraph engineers). *Also I find that Dr. Hertz has made experiments on electric oscillations very like those of mine on 'the surging circuit'* (Wied. Ann., 1887)."[26]

By reading Hertz's work sometime prior to June 22, 1888, Lodge would have discovered that Hertz invented a new oscillator that produced very short wavelengths on the order of a few meters—the same dimensions as the length of wires he was exciting by both direct connections between the oscillator and wire circuits and by exposures of isolated secondary circuits located at short distances from the oscillator. Lodge would also have found that Hertz:

- observed resonances in rectangular loops when the circumferences of the loops had the same dimensions as the emitted wavelengths,
- observed nodes and antinodes indicating there were standing waves on the wires, which he determined by measuring the potential differences between wires at critical nodes and antinodes using a pair of discharge knobs, and
- calculated the resonant frequency of his dipole oscillator and compared it to the measured resonant wavelength of his loop detector that had been excited by his dipole oscillator.

While Lodge's reference to Wiedemann's *Annalen der Physik* in 1887 is not specific, Hertz published only three papers in *Annalen* during the entire year of 1887, and one of them was on the effect ultraviolet light had on spark strength. The other two were specific to the subject of surging currents, and they both appeared in the same issue of *Annalen*—Vol. 31, Issue No. 7, which was dated May 15, 1887. The first article described Hertz's earlier researches—including the observations of standing waves on wires produced by resonances between his disruptive discharge oscillator and the wires. The second article was an addendum to the first in which Hertz clarified that he had not been the first

to report observations of standing waves on wires—as he had implied in his first article. In the second article, consisting of a single paragraph, Hertz gave the credit for discovering standing waves on resonant wires to Professor Wilhelm von Bezold, who had reported similar observations at the Bavarian Academy of Sciences on February 5, 1870. Bezold's paper had been reproduced in the *Philosophical Magazine*, which was published in July 1870.[27] Undoubtedly, Lodge also read Bezold's paper referenced by Hertz in the same issue of *Annalen*, and he may also have read Bezold's paper in the *Philosophical Magazine*, with which he had a close association.

The fact that Lodge had become familiar with Hertz's work with waves on wires before he (Lodge) published any of his work on this subject dramatically changes the way historians must look at Lodge's discoveries of standing waves on wires. Most historians have missed this point. For example, Aitken writes: "In Lodge's last publication before he had learned what Hertz had been up to, the experimental arrangement is shown in its bare essentials and the theoretical issue stated succinctly."[28] The paper to which Aitken referred in this citation was Lodge's *second* publication on this subject dated July 17, 1888, which was published in the *Philosophical Magazine* in August 1888.[29] The truth is that Lodge admitted to reading Hertz's 1887 paper disclosing his discovery of standing waves on wires and associated resonances with his dipole oscillator source before Lodge published his first paper on the subject of standing waves on wires.

While there is no way to determine exactly when Lodge actually read Hertz's 1887 paper, it was certainly before Lodge completed his first paper for publication that described his discovery of standing waves on wires. To keep dates of priority in perspective, Hertz had actually submitted the paper Lodge read to *Annalen der Physik* with the date March 23, 1887, which was almost a year before Lodge began his first recoil kick experiments on March 1, 1888, the date that Lodge had later recalled.[30] Hertz's first paper on the subject of waves on wires was published on May 15, 1887, while Lodge's very first paper documenting his recoil kick experiment was published on June 22, 1888.

Hertz's Publications between May 1887 and May 1888

Lodge may also have been influenced by something that he read in other papers that Hertz published between May 27, 1887, and June 22, 1888. While there is no way to know what Lodge read, it is worth taking stock of what Hertz published during that period to see if there is any correlation between Hertz's work during that period and Lodge's later publications. Hertz published eight of his papers on the discovery of electromagnetic waves on wires and in free space between May 15, 1887, and May 20, 1888—all before Lodge's first publication on the recoil kick experiment appeared on June 22, 1888. The dates of publication of all eight are listed in Table 1. Also included in the table are the titles of the papers in English, the dates on the manuscripts submitted to

Table 1. Hertz Papers Published in* Annalen der physik *between May 1887 and May 1888.

Hertz Paper Title	Annalen Der Physik	Submission Date	Publication Date	Chap. No.
On Very Rapid Electric Oscillations	Vol. 31 No. 7	Mar. 23, 1887	May 15, 1887	2
Addendum to the Treatise On Very Rapid Electric Oscillations	Vol. 31 No. 7	c. May 1887	May 15, 1887	3
On an Effect of Ultra-Violet Light upon the Electric Discharge	Vol. 31 No. 8	May 27, 1887	July 1, 1887	4
On the Action of a Rectilinear Electric Oscillation upon a Neighboring Circuit	Vol. 34 No. 5	Feb. 1888	Mar. 15, 1888	5
On Electromagnetic Effects Produced by Electrical Disturbances in Insulators	Vol. 34 No. 6	Nov. 5, 1887	Apr. 15, 1888	6
On the Finite Velocity of Propagation of Electromagnetic Actions	Vol. 34 No. 7	Jan. 21, 1888	May 15, 1888 Feb. 9, 1888*	7
On Electromagnetic Waves in Air and their Reflection	Vol. 34 No. 8(a)	Apr. 1888	May 20, 1888	8

*First published on Feb. 9, 1888, in *Sitzungsberichte der Preussischen Akademie der Wissenschaften*.

Wiedemann's *Annalen*, and the chapter numbers in Hertz's book *Electric Waves*, which provides a translation of each. The dates of submission and publication have been confirmed by obtaining original copies of the relevant *Annalen der Physik* issues and also by comparing the dates with those published by IEEE Fellow John H. Bryant.[31]

The following is a summary of what Hertz disclosed in the publications listed in this table according to the publication dates that appear in the fourth column. The second paper listed in the table is a short one-paragraph paper in which Hertz wished to inform readers that he had just learned that Bezold had discovered resonances on wires before he had. This publication is not included in the list that follows.

- **(May 15, 1887 Publication):** Hertz discovered standing waves on wires produced by resonances between his dipole oscillator source and harmonics of the standing waves he observed on wires in various configurations. He invented the Hertz rectilinear (dipole) oscillator as a source of electromagnetic radiation with very short waves, and he demonstrated that standing waves were produced when the source wavelength was in resonance with an isolated rectangular loop. He introduced a method to calculate the resonant period of his source T_S using the basic equation $T_S = 2\pi\sqrt{(LC)}$ and the resonant period of his source T_W using the basic equation $T_W = \lambda/v$, where λ was the wavelength he determined by measurement, and v was the velocity of the waves on the wires. In this paper, Hertz assumed the velocity of the wave on the wires was equal to the speed of light, but he later calculated the speed of the waves on wires by directly measuring the wavelength

of the standing waves with resonant loop detectors, equating the two periods ($T_W = T_S$), and solving for v.

- **(July 1, 1887 Publication):** Hertz discovered that the exposure of spark discharges to ultraviolet light enhanced the spark length. In September 1888 at Bath, Lodge revealed that he had read Hertz's paper and had repeated Hertz's experiment with ultraviolet light, which means that Lodge knew about this paper while he was performing experiments earlier with his Leyden jars.[32] It also means that Lodge was indeed tracking and reading Hertz's other work after he read the first reference dating from May 1887.
- **(March 15, 1888 Publication):** Hertz mapped the electric fields around his dipole radiator and found that electromagnetic force (proportional to the electric field) was inversely proportional to the distance, whereas the electrostatic force was inversely proportional to the third power of the distance. He also found that the transition distance was at a distance of approximately half a wavelength from the dipole axis.
- **(April 15, 1888 Publication):** Hertz described the electromagnetic effects produced by electric wave disturbances in insulators. This subject is not particularly relevant to Lodge's claims of discovering electromagnetic waves on wires or in air.
- **(May 15, 1888 Publication):** In November of 1887, Hertz used his dipole oscillator to excite a long wire terminated by a short circuit at the end, and he measured the period T_W of the resulting standing waves on the wire. Hertz did this by mapping out the nodes and loops with the resonant loop detector that he developed earlier (see Fig. 3). He used the resulting data to calculate the velocity of propagation v on the wire using the basic equations for wave velocity, $v = \lambda/T_W$, and the calculated resonant period of his source, $T_S = 2\pi\sqrt{(LC)}$.
- **(May 20, 1888 Publication):** Hertz discovered and measured the nodes and loops of propagating electromagnetic waves in air as they formed an interference pattern by reflecting off of a conducting plate, which was the first experimental determination that electromagnetic waves existed in free space and the speed of waves in free space was equal to the speed of light (see Fig. 4). Oliver Lodge claimed he first read this paper in early July 1888 while traveling to Cortina, Italy.

Hertz's Publication Disclosing Waves on Long Wires was First Published in February 1888

Hertz's publication disclosing standing waves on wires and his calculation of the speed of waves on wires published in *Annalen der Physik* in the issue dated May 15, 1888, was actually first published in an issue of *Sitzungsberichte der Preussischen Akademie der Wissenschaften* dated February 9, 1887, a prominent publication in Berlin, and it was later reproduced in *Annalen der Physik*. A strong argument can be made that Lodge first heard about Hertz measuring standing waves on wires in the publication of

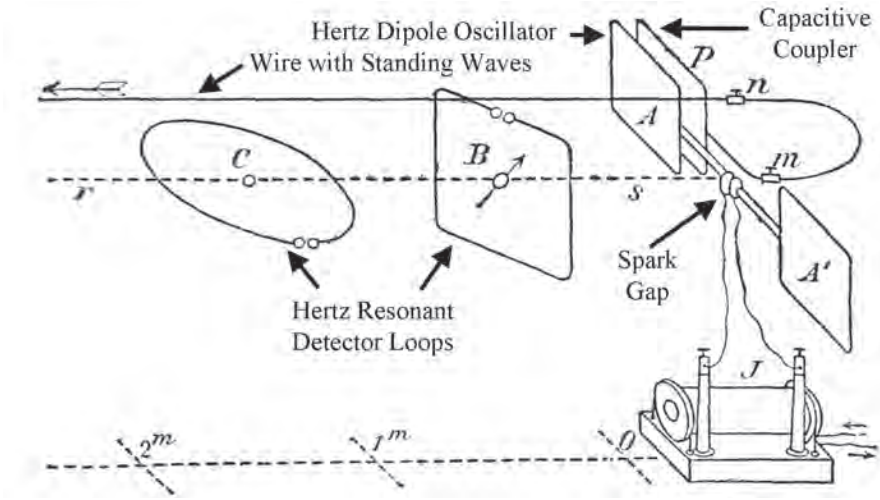
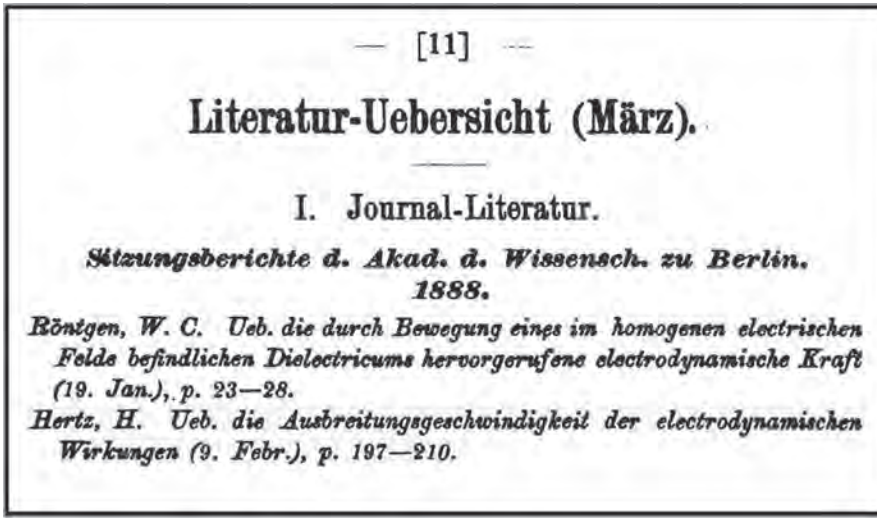


Fig. 3. Using his resonant loop with gap detectors, Hertz measured the distance between nodes and loops of stationary waves excited on a long wire by his dipole oscillator. (Hertz, *Electric Waves*, p.108)



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Röntgen, W. C. Ueb. die durch Bewegung eines im homogenen electrischen Felde befindlichen Dielectricums hervorgerufene electrodynamische Kraft (19. Jan.), p. 23—28.

Hertz, H. Ueb. die Ausbreitungsgeschwindigkeit der electrodynamischen Wirkungen (9. Febr.), p. 197—210.

Fig. 4. The fact that Hertz had published a paper with a calculation of the speed of waves on wires by the *Akademie der Wissenschaften* of Berlin on February 9, 1888, appeared prominently on the first page of the monthly supplement to Annalen der Physik, *Beiblätter zu den Annalen der Physik un Chemie,* dated March 1888. (*Beiblätter,* March 1888)

Akademie der Wissenschaften sometime in March 1888. It turns out that *Annalen der Physik* published a monthly supplement (beiblätter) to the regular issues of this journal entitled *Beiblätter zu den Annalen der Physik un Chemie*, and it also turns out that this paper by Hertz appeared prominently on the first page of the March 1888 issue of this supplement (see Fig. 5). It is well known that Lodge was an avid reader of technical journals of the day and that he regularly received copies of the publication *Annalen der Physik*. It is probable that he received the supplement as part of his subscription to *Annalen der Physik*, because it contained timely abstracts of the latest work of science.

If for some reason Lodge did not read this issue of *Beiblätter*, he surely would not have missed the following article that appeared in *Nature* magazine, a periodical that Lodge often used for his publications. This publication had a paragraph under a section titled "Berlin," which often appeared in *Nature* that featured scientific research and associated developments in Berlin. In the issue dated March 8, 1888, *Nature* reported on talks at a meeting of the Physical Society in Germany that was chaired by Professor von Helmholtz. In one of these talks Hertz described his discovery of waves on wires and his calculation of the speed of the waves on wires:

> "The other [presentation] due to Prof. Hertz, has for its subject the rate of propagation of electro-dynamic action. By an extremely ingenious method, which the speaker explained, and which has been used by Prof. Hertz, in many of his previous researches, for the measurement of electrical vibrations, he has succeeded in proving that electricity is propagated along a metallic wire at the rate of 200,000 kilometers per second, and that electro-dynamic action passes through dielectrics with the velocity of light. These experiments

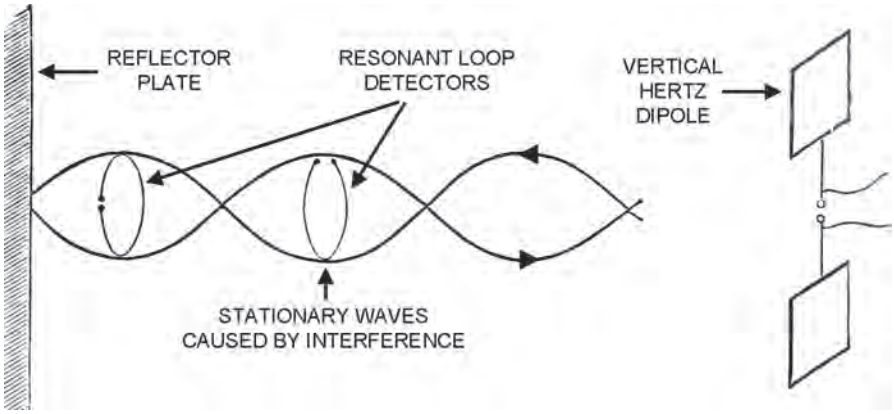


Fig. 5. Using his resonant loop detectors and his dipole oscillator in the vertical orientation, Hertz observed interference patterns to detect true electromagnetic radiation in free space and measured their wavelengths. (Alamy Stock Image RJAF4M)

> thus provide the experimental confirmation of the Faraday-Maxwell theory of electro-dynamic action."[33]

Hertz's calculation predicting the speed of electric waves on wires was two-thirds the speed of light caused some consternation within the scientific community. Surely, Lodge would have been very interested in this article. The facts surrounding this prediction are summarized in the sidebar appearing on the following page entitled "Hertz's Calculation of Wave Speed on Wires." This sidebar provides evidence of how Hertz measured standing waves on wires, how he calculated the speed of waves on wires, and how he made an error in the calculation by miscalculating the capacitance of his dipole oscillator—not by any mistake or error in the measurement of the waves on wires. If Lodge had missed this earlier version of Hertz's paper dealing with standing waves on wires published in February 1888, it is unlikely that he missed the same article published in the issue of *Annalen de Physik* dated May 15, 1888. This issue was published before the last paper in the table, which is the paper that Lodge claimed he read in mid-July.

Regardless of whether Lodge read any of Hertz's subsequent papers listed above, all of Hertz's papers listed in this table had been published by Hertz well before Lodge's first paper describing his observations of standing waves on wires was published on June 22, 1888. Consequently, Hertz had priority in the discovery of both standing waves on wires excited by a source with the same frequency as a harmonic of the standing waves on wires and electromagnetic waves propagating in free space. Both were discovered by observing the stationary waves produced by interference between waves propagating in opposite directions—in the first case by reflections from the termination at the end of a wire, and in the second case by reflections of electromagnetic waves from a conducting plate.

Lodge Documented his Recoil Kick Experiment (June 22, 1888)

While Lodge disclosed his recoil kick experiment at a lecture on lightning conductors to the Society of Arts on March 17, 1888, there is no written record of what he actually said about the results of his recoil kick experiment at that lecture. Lodge did not document his experiments until three months later when it first appeared in an issue of the *Journal of the Society of Arts* published on June 22, 1888—after Lodge admitted he read Hertz's paper. While Lodge did not explain how he came across the recoil kick experiment in his paper, he did describe how he discovered standing waves in the course of his recoil kick experiments at the British Association meeting in Bath:

> "I happened to be experimenting on lightning conduction, and somewhat to my surprise, as an outcome from those experiments, I hit on an arrangement which, without any thought or scheming at all, gave me evidence of the very waves I had been thinking so much about, and enabled me to measure their lengths, though not in a previously planned-out way. I described

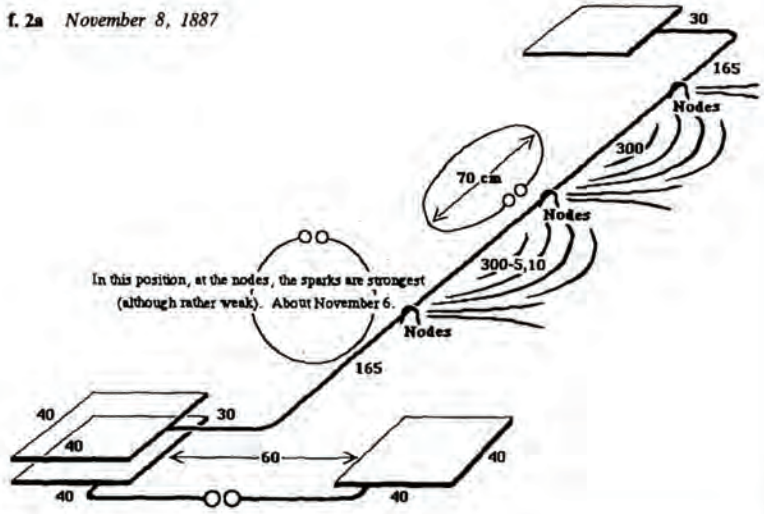
Hertz's Calculation of Wave Speed on Wires

According to his laboratory notebook dated November 8, 1887,* Hertz recorded the nodes and loops of standing waves that he observed on his single wire, which was grounded at the far end, using his resonant loop detectors (see figure below). In order to create the nodes and loops, Hertz emphasized that he had to vary the length of the wires until the source and wire were in resonance, which he found to occur on his wire for lengths of 5.5 and 8 meters. In both cases, he measured the distance between the nodal points and found them to be uniformly spaced at 2.8 meters, which represented half the wavelength of the standing waves. He recognized that the corresponding half period of the wave on the wire depended on the velocity v of the wave, $T_{W½} = ½\,\lambda/v = (2.8\text{ m})/v$.

Hertz then calculated half the resonant period of his source using the equation $T_{S½} = \pi\sqrt{LC} = 1.4 \times 10^{-8}$ seconds. Note the usual factor of 2 is missing from this equation because it represents only half the period. Finally, Hertz equated the two half periods $T_{W½} = T_{S½}$ and solved for the velocity $v = (2.8\text{ m})/(1.4\times10^{-8}\text{ s}) = 200$ km/s. Hertz concluded only that it was the correct order of magnitude: "Since it was obtained with the aid of a doubtful theory, we are not justified in publishing it as a new measurement of this same velocity; but, on the other hand, we may conclude, from the accordance between the experimental results, that our calculated value of the period of oscillation is of the right order of magnitude."

In fact, Hertz soon realized that his calculation of the capacitance of his source was twice what it should have been. After correcting the value of capacitance in his equation the period of the source was reduced by $\sqrt{2}$ and the resulting calculated speed of light became 280 km/s. In the end, his experimental technique and his technique of calculating the speed of waves on wires proved to be correct.

*D. Baird, R. Hughes, and A. Nordman, *Heinrich Hertz: Classical Physicist, Modern Philosopher*, (Kluwer Academic Publishers, Dordrecht/Boston/London, 1998) p. 73.



these experiments quite hastily and briefly in the midst of other matter, in a lecture to the Society of Arts last March on lightning conductors, as 'the experiment of the recoil kick'."[34]

Lodge's recoil kick experiment consisted of two Leyden jars in series attached to two parallel wires 95 feet long (30 meters) that were spaced 50 cm apart with no load, thus forming a transmission line with an open circuit at the far end (Fig. 6). The two jars and the wires were charged to a high voltage by an electrostatic machine and subsequently discharged by two spherical discharge knobs, located at point A on his electrostatic machine, which were set to a preselected gap spacing. The resulting potential differences appearing across the wires at points B_1 nearest the source, B_2 at the midpoint, and B_3 at the far end were determined by recording the spacing of the largest spark gap at each point that was just able to produce a feeble spark discharge.

This procedure resulted in measuring the largest gap that appeared at each spark detector during the *entire* transient, not necessarily during the time standing waves might have formed. Note that the wires were initially charged to the high voltage set by the spark gap at point A. Hertz did not have this problem because he did not measure the potential between two wires like Lodge; instead, Hertz used his resonant loops to map out the loops and nodes (see previous sidebar).

Since the breakdown threshold for spark discharge knobs in dry air at sea

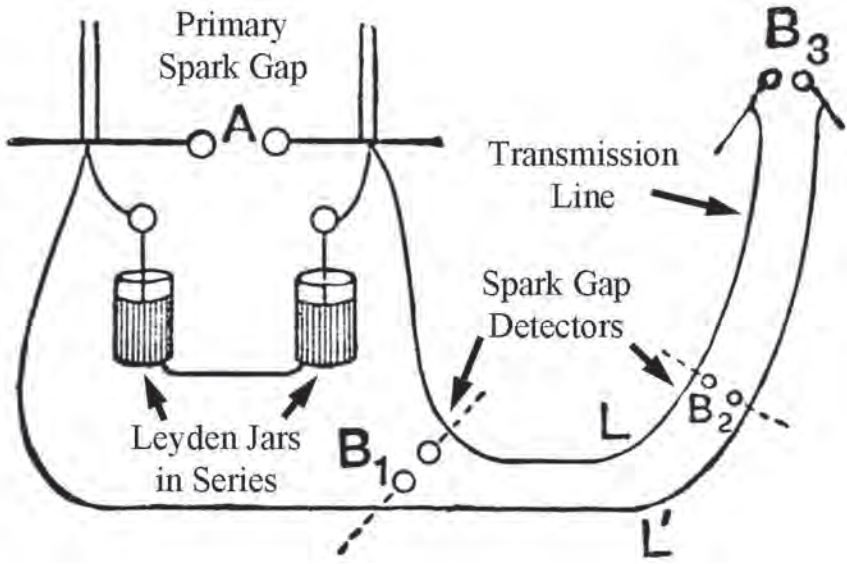


Fig. 6. Lodge's recoil kick experiment consisted of two Leyden jars in series attached to two parallel wires with no load at the end, a configuration that formed a transmission line with an open circuit at the far end where reflections (recoil kicks) were able to double the magnitude of the potential difference applied to the input. (*J. Soc. Arts*, Vol. 36, p. 889)

level is approximately 30 kV/cm, the potential difference between two knobs could be inferred from the product of the breakdown threshold of air (30 kV/cm) and the largest gap spacing that was just able to produce a spark. For example, a maximum sparking gap distance of one centimeter represented a potential difference of 30 kV/cm × 1 cm, or 30 kV between the two wires.

Lodge began this experiment by setting each of the detector spark gaps at the three B locations to a spacing slightly less than that of the primary discharge gap at A of the electrostatic machine, one at a time, so that the B gaps would discharge rather than the A gap. This was to be expected because the A gap and the three B gaps were slowly and simultaneously charged to the same potential by the electrostatic machine, and the first discharge occurred at the spark gap with the smallest spacing, regardless of whether it was the primary spark gap at A or the spark gap detectors at the three B points.

Lodge then increased the spacing of the knobs at the three B measurement points, one at a time, so that each gap was slightly larger than the primary spark gap at A—thus allowing the spark gap at A to discharge first. Lodge suggested that the uninitiated engineer might have believed that no sparks would occur at any of the three spark gaps at B after the discharge at A shorted out the wires, but instead, each of the three B spark detectors on the line, in turn, produced spark discharges at the instant the primary gap discharged at A. Not only that, but the spark gap at the end of the line at B_3 produced the largest spark, which was about twice the length of the spark produced by the primary spark gap at A.

Lodge Records his Recoil Kick Data

Lodge then explained how he obtained and recorded the data from his recoil kick experiment. Referring again to Fig. 6, Lodge set the spark gap at one point on the line, say at B_1, to a preselected gap setting, say 3.22 tenths of an inch. He then increased the spark gap spacing at the source A until he found the spacing that just produced a spark at B_1. This procedure was repeated for the knobs at other two measurement points B_2 and B_3 using the same preset knob spacing he used at B_1 (3.22 tenths of an inch in this example). The objective was to examine and record the ratio of the spark lengths B_i/A, which indicated how much longer the B sparks were than the A sparks, which in turn indicated how much larger the potential differences were at the B points relative to the potential difference at point A, which was the source of the excitation.

To determine the sensitivity of the ratios B_i/A to the spark length at A, this process was repeated two more times for two different preset knob spacings at the three B points. The three preset gap spacings at B were chosen to be 3.22, 4.80, and 6.18 tenths of an inch. All this data was assembled and presented in a tabular format similar to the one shown in the column labeled "Spark Lengths" in Table 2. Lodge presented data only for the three preset gap spacings at the B locations for his largest Leyden jar

Table 2. Lodge's data from his recoil kick experiment with gallon-sized Leyden jars in series performed in March of 1888.

Measurement Position	Spark Measurement Location	Spark Lengths (tenths of an inch)			Spark Gap Ratios (B_i/A) (representing V_i/V_0)*		
B_1: closest to spark source	Minimum spark lengths at A:	3.2	4.15	5.12	1.	1.2	1.2
	Preset knob spacing at B_1:	3.22	4.80	6.18		(1)	(1)
B_2: mid point of wire	Minimum spark lengths at A:	1.92	2.37	2.7	1.7	2.0	2.3
	Preset knob spacing at B_2:	3.22	4.80	6.18		(1.7)	(1.9)
B_3: far end of wire ($Z_L = \infty$)	Minimum spark lengths at A:	1.6	2.2	2.45	2.0	2.2	2.5
	Preset knob spacing at B_3:	3.22	4.80	6.18		(1.8)	(2.1)

*Ratios in parentheses have been corrected to account for differences in spark gap knob diameters of the primary discharge knob at A and the sensor knobs at the three B locations on the wire (see text).

capacitance (gallon-sized jars); these gaps are highlighted by the shaded rows in his raw data labeled "Spark Lengths."

Lodge stated that the absolute numbers were not particularly relevant; instead, it was the ratios of the spark gap lengths B_i/A that were important, because they represented the voltage ratios V_i/V_0. Lodge did not show these ratios in his paper, but they have been calculated by the author and displayed in the far right columns labeled "Spark Gap Ratios." Note that the ratios of the responses depend on the size of the spark at A, which represents the initial voltage V_0 before the discharge at A occurs. In theory, the ratios should not be dependent on the spark gap size (i.e., voltage) at A, but Lodge did not give any reason for the nonlinearity in his 1888 paper.

It turns out that Lodge withheld a critical piece of information from this paper, which he disclosed in a paper published three years later in 1891:

> "And because the knobs machine and discharger were not of the same size, they were first compared by letting an ordinary discharge choose between them. They offered equally good paths when A = 0.45, B = 0.54 inch."[35]

This data revealed that the voltage across the gap was a function of the radius of the discharge knobs. In fact, it was well known at the time that the breakdown threshold of air in the gap between two spheres depended on the radius of the spheres when the gap size was not small compared to the radius.[36] Lodge never gave dimensions of the two types of knobs but it is likely that the detector knobs were as small as possible to minimize the perturbation of the electric field in the gap. It follows that the smaller the gap sizes, the less likely the voltages across pairs of knobs would be dependent on the radii of the knobs.

Based on Lodge's measurement of the B gap 0.54 inches when the A gap was 0.45 inches, the larger ratios in the far right column would have to be adjusted downward by a factor 0.83 (e.g., 0.45/0.54 = 0.83) to account for the fact that when voltage across the two gaps are the same, the gap at B is larger than the gap size at A. This correction to the ratios is applied in the numbers

in parentheses in two columns to the far right of Table 2, where the gaps of the B_2 and B_3 are the largest. This adjustment takes much of the variation out of the results, and it appears that the ratio of the gaps at B_3 to A are very close to a factor of two, which is consistent with a reflection, not a large increase in the recoil kick arising from a resonance—as Lodge suggested.

Lodge was particularly interested in the magnitude of the response at the end of the wires at point B_3 where the response to a discharge at A was largest. Presumably, Lodge was interested in this point because the goal of the recoil kick experiment was to show that the actual responses were often different from the responses that might be expected by the uninitiated. Lodge set out to determine the sensitivity of his results to the frequency of his source, and to that end he used three different values of capacitance: two pint-sized Leyden jars in series, two gallon-sized Leyden jars in series, and a very large capacitor of alternating glass and tinfoil sheets. For purposes of comparison, Lodge chose a fixed spark length of 4.5 tenths of an inch for his source at position A, and he recorded the maximum gap spacing at B_3 that would produce a spark for the three capacitors (see Table 3).

It is apparent that Lodge chose to publish the data for the two gallon-sized jars in series because those jars produced the largest response at the end of the wires for the three capacitors. All of the data Lodge presented with the two gallon-sized jars in series are consistent with the largest response being caused by a recoil kick, or reflection, which would produce a doubling of the potential at the far end point without a resonance.

Lodge Explains the Theory for the Recoil Kick Experiment

Lodge named this experiment "recoil kick" after the recoil impulse or kick by the reflection of the wave at the end of an open transmission line: "The electricity in the long wires is surging to and fro, like water in a bath when it has been tilted; and the long spark at the far end of the wires is due to the recoil impulse or kick at the reflexion of the wave."[37] It is well known that the reflection coefficient at the end of an open transmission line is plus one, and the reflected portion of the pulse is positive, which generally doubles the voltage there. While this fact may have been known by some scientists and telegraphers, it would have been a surprise to most engineers of the day dealing with lightning conductors and protectors. Therefore, this experiment would

Table 3. Comparisons of response ratios B_3/A at the end of the 30 meter wires for the three capacitor sizes used for the spark discharge source.

Capacitor size	Spark Length at A (tenths-of-an-inch)	Spark Length at B_3 (tenths-of-an-inch)	Gap Length Ratio (B_3/A)
Pint jar (2 in series)	4.5	7.8	1.7
Gallon jar (2 in series)	4.5	10.9	2.4
Glass and foil sheets	4.5	5.9	1.3

certainly have satisfied the objectives that Lodge set out for his lightning conductor experiments, which was to demonstrate unexpected results from his high voltage, high-frequency discharges of Leyden jars into various wiring configurations.

Lodge could have stopped right there with a very successful experiment, but he decided to go one step further by claiming that there was a quantitative relationship between the length of the wires and three capacitors he used in his source, as listed in Table 3. Referring to responses produced by the three different capacitors listed in Table 3, Lodge wrote:

> "Evidently there are some quantitative relations to be specified here, and there will be some best capacity of the jars corresponding to a given length of conductor, and to a given arrangement of main discharge circuit, A. The nearer the length of the conductors corresponds to a half-wave [sic] length, or some multiple of a half-wave [sic] length, of the oscillations produced by the discharging jars, the more perfect will be the synchronism between the pulses, and a longer recoil kick may be expected. The arrangement may in fact be compared to Melde's experiment with vibrating strings or to any other case of forced vibration."[38]

As mentioned previously, Lodge claimed that he "hit on an arrangement which, without any thought or scheming at all, gave me evidence of the very waves I had been thinking so much about and enabled me to measure their lengths, though not in a previously planned-out way."[39] However, none of the data Lodge presented remotely suggested that there were standing waves on the line, much less that the standing waves were "a half wave-length of the oscillations produced by the discharging jars." It will be shown next that Lodge's claims of observing evidence of standing waves "without thought or scheming" are not true.

Lodge Did Not Observe or Measure Standing Waves with his Recoil Kick Experiment

Referring to the data in Table 3, Lodge noted that the capacity of the two gallon-sized jars in series gave the best result—meaning, that of the three capacitors, it was two gallon-sized jars used in the source that produced the largest measured voltage at the end of the wire:

> "The capacity of the two gallon jars in series (this being the capacity which gave the best result with 95 feet of leads) was about .002 microfarad, or, say, 1,800 centimetres."

The largest response at the end of the line produced by the two gallon-sized jars appearing in Table 3 was between 2.0 and 2.4 times the voltage that was applied to the transmission line by the discharge of the source. As pointed out previously, the most accurate ratio was most likely for the smallest gap size, which was approximately 2.0, exactly what would be expected from a single recoil kick, or reflection, at the end of the wire.

The fact that the two gallon-sized jars in series produced the largest response

of the three capacitors is not evidence that there was a resonance. There are other explanations for variations in the magnitude of the response at the end of the wires for the three different capacitors that have nothing to do with resonances. For example, the magnitude of the response on a transmission line in steady state depends on the reflection coefficients at both ends of the line. When the load impedances at both ends of a line are matched to the transmission line impedance (both reflection coefficients are zero), there are no reflections and no standing waves, and assuming there are no losses in the transmission line, the maximum response at the output equals the maximum response at the input.

When the far end is open-circuited and the source impedance is matched to the line (reflection coefficient at the source is zero), the reflection coefficient at the open end is plus one, thereby returning a signal that adds to the incident signal. However, when the signal reflected from the open end returns to the matched load at the source where the reflection coefficient is zero, there is no reflection and there are no resonances on the line. Therefore the voltage at the open end of the line is limited to a maximum of twice the input voltage on the line from reflections only.

If the impedance of the source is not matched to the line impedance, the reflection coefficient at the source can be either positive or negative, depending on the source impedance relative to the line impedance. If the reflection coefficient is positive, the reflection will add to the signal generated at the source, but if it is negative, it will subtract from the signal generated at the source. The reflection coefficients at the source of Lodge's line are clearly different for each of the three capacitor configurations used for the source, since physical dimensions controlling the inductance, capacitance, and resistance of the capacitors are different for each. These differences can easily explain the relatively small variations in the magnitudes of the maximum response ratios B_i/A Lodge measured at the end of the line (1.3, 1.7, and 2.4) for the three different capacitances.

Whatever the reason for the maximum response produced by the gallon-sized jars, Lodge's data in Table 2 provides irrefutable evidence that there were no standing waves on his 95 foot (30 meter) cable that matches any known harmonics for standing-wave resonances, much less the primary harmonic for a half-wavelength resonance, which is what Lodge claimed he had observed. The data for Lodge's two gallon-sized jars in series presented in Table 2 is plotted on a standing wave pattern for a half-wavelength resonance pattern shown in Fig. 7. The circled numbers represent the three data points from Lodge's experiment that appear in Table 1 (in the third column from the far right: $B_1 = V_0$, $B_2 = 1.7V_0$, $B_3 = 2.0V_0$. The voltage V_0 represents the amplitude at the discharge point A. What is obvious from the data using his gallon-sized jars is that the data does not match Lodge's claim that he observed a half-wavelength resonance.

The amplitude at the endpoint of the cable (B_3) is twice the voltage V_0 at point A, which is to be expected for either a

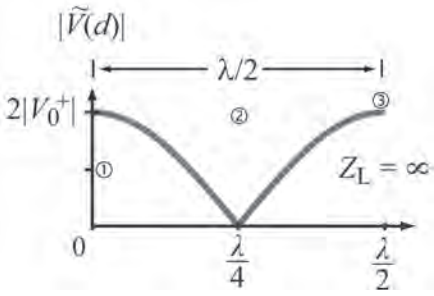


Fig. 7. The data for Lodge's two gallon-sized jars, represented by the circled numbers, do not match the standing wave pattern for the half-wavelength resonance that Lodge claimed he observed. (Author)

reflection or perhaps a half-wavelength resonance. However, the voltage at the midpoint (B_2) is about seven tenths of the maximum at the end of the cable, but it is supposed to be a null point for the first harmonic of a half-wavelength resonance. The data point at B_1 nearest the source is most suspicious. The amplitude there is equal to V_0, but it should be twice that value for a half-wavelength resonance, since the amplitude at both ends of the cable should be equal for all harmonics of a half-wavelength standing wave. Clearly there is something awry with Lodge's claim that his data led him to believe he had observed a half-wavelength resonance and that the response would be largest for some harmonic of a half-wavelength resonance.

Worse yet, a half-wavelength resonance is not the first harmonic for a transmission line with an open circuit at the far end, as Lodge claimed. The first harmonic is a quarter-wavelength resonance (see Fig. 8).[40] A half-wavelength

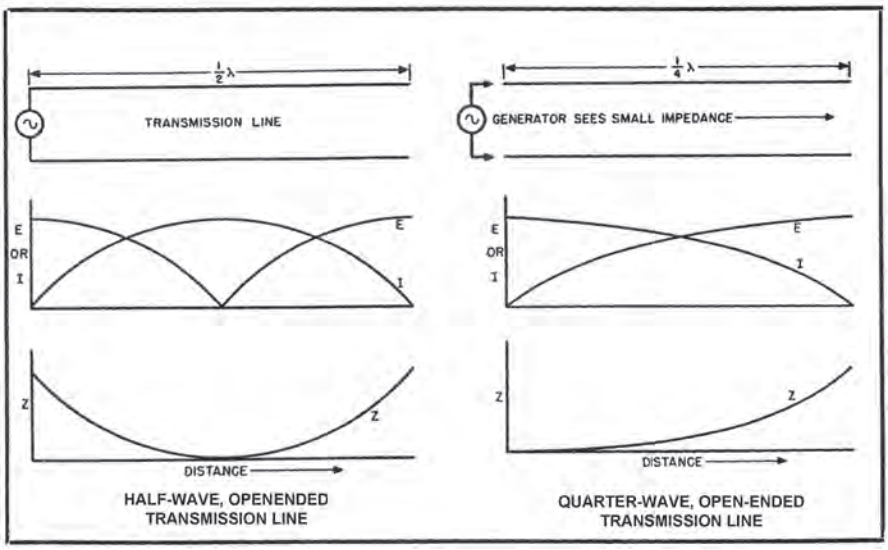


Fig. 8. Relative values of voltage, current, and impedance on open-ended quarter-wave and half-wave transmission lines; the first harmonic for an open-ended transmission line is actually a quarter-wavelength resonance, not a half-wavelength resonance as Lodge claimed. (M. Kiver, *Radio News*, May 1944, pp. 50–52, 106)

resonance is actually the second harmonic. Assuming that Lodge actually created a resonance on his 30 meter cable with his two gallon-sized jars in series, there is no reason to believe that the second harmonic would have produced a larger response at the end of the cable than either the first or third harmonic. Lodge did not vary the length of his wire over the range necessary to determine which harmonic he was observing, if any. Consequently, there is no justification for Lodge to have inferred from his data that he observed a harmonic of a half-wavelength resonance for his 30 meter wire configuration.

When Lodge's data is plotted on a standing wave pattern for a quarter-wavelength resonance, it appears that it is closer to being the first harmonic of a quarter-wavelength resonance as opposed to a half-wavelength resonance (see Fig. 9). The main discrepancy is the amplitude at point B_1 nearest to the source, which would have been zero for a quarter-wavelength resonance as opposed to Lodge's amplitude measurement of V_0.

Recall that Lodge's measurement technique could not record responses *less* than the amplitude of A, corresponding to V_0. Since Lodge's apparatus was unable to register an amplitude less than that at point A, it is possible that the actual amplitude at B_1 was zero, but it is more likely that Lodge did not produce a resonance with his two gallon-sized jars in series. This is a fundamental problem with Lodge's recoil kick experimental configuration: it does not characterize standing waves. It cannot be used to

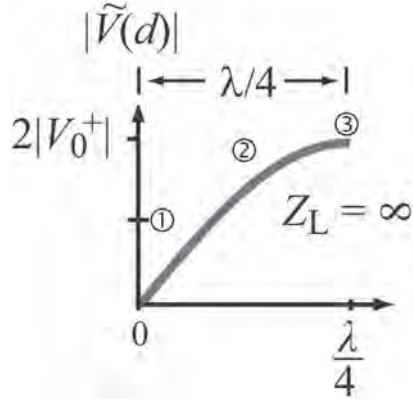


Fig. 9. The data for Lodge's two gallon-sized jars in series, represented by the circled numbers, do not match the standing wave pattern for a quarter-wavelength resonance. (Author)

observe nulls, and it records the largest signals at each measurement point during the entire transient from the time the line is charged to the time steady state is reached. The steady-state signals for the standing waves at each point are generally not as large as the signals reached during the transient. The peak signals measured on Lodge's sensors will appear at various points on the wires at different times during the transient. In essence, Lodge's recoil kick experimental configuration generates rather random signals, except at the end of the wire where the response is greatest.

Lodge Falsely Claimed he Measured Resonances by the Glow on the Wires

Lodge would later claim that he was able to observe and measure the nodes and antinodes by the brushes (glow) the wires gave off at the antinodes, and the dark sections that appeared at the nodal points:

> "One had only to lengthen the wires enough, and to look at them in the dark, to see by the brushes the nodes caused by the interference of the direct and reflected pulses surging to and fro in the wires; to see in fact the waves themselves, and to measure their length in a manner precisely analogous to the well-known experiment of Melde."[41]

There is no evidence that Lodge ever was able to do that, but more to the point, Lodge claimed in his July 1888 paper that he had observed the glow only at the *far end of the cable*, which is consistent with a reflection at the far end but it is inconsistent with the half-wavelength standing wave that he claimed he observed in his paper published on June 22, 1888:

> "Removing the discharger altogether [discharge knobs at measurement point B_3], and making the experiment in the dark, a very interesting effect is seen; *the further end of each wire glows* [emphasis added] with a vivid brush light; showing the exceedingly high potential to which they are raised by the recoil.… With the two gallon jars the wires glow over fully three-fifths of their entire length. With jars of much larger or much smaller capacity the length of glow is conspicuously less."[42]

If Lodge had actually observed a half-wavelength resonance by the vivid brush light, there would have been a large brush of equal magnitude at either end of the wires, and a dark region or regions between the two glowing portions at the ends. Lodge never reported that observation.

Lodge's Specious Calculation to Support His Claims of Standing Waves

In an attempt to convince himself that he had observed a half-wavelength resonance with his recoil kick experiment, Lodge proposed a rather convoluted calculation in June 1888. Lodge used the same equations that appeared in Hertz's 1887 paper, but with a very different approach. Hertz, in his 1887 paper, described how he measured the resonant wavelength of one of his resonant loops with a spark gap detector exposed by his Hertz dipole oscillator (see Fig. 10). He varied the circumference of his detector from approximately 200 to 700 cm and plotted the maximum spark length as a function of circumference length to find the circumference that produced the largest response in his spark gap detector, which turned out to be about 450 cm (see

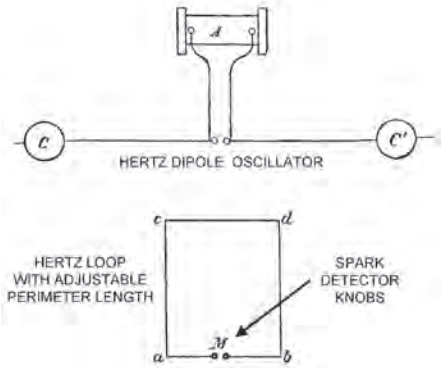


Fig. 10. Hertz used his dipole oscillator with spherical loads to excite a resonance in his resonant loop detector, which he found by varying the length of the perimeter wire in the loop. (Hertz, *Electric Waves*, p. 40, modified)

Fig. 11). He assumed the circumference of his resonant loop was approximately equal to its resonant wavelength. He then estimated the capacitance and inductance of his dipole oscillator, from which he estimated the period of his source by using the equation $T = 2\pi\sqrt{(LC)}$. Finally, he calculated the wavelength of his source using the well-known relationship between the wavelength, period, and velocity of the wave, $\lambda = Tv$. He assumed the velocity of the wave was equal to the speed of light in free space and calculated the wavelength of his source to be about 5.3 meters. By comparing the calculated wavelength of his source to the measured length of the loop at the point of resonance, he then concluded that the measured wavelength at resonance was a close match to the wavelength produced by his dipole source, and that his dipole source produced a standing wave in his loop.

Lodge's approach was quite different, primarily because he never varied the length of his wires to determine by experiment the wire length that produced a maximum in the response at the open end of his wires. Lodge described his entire analysis approach in a single rather incomprehensible paragraph as follows:

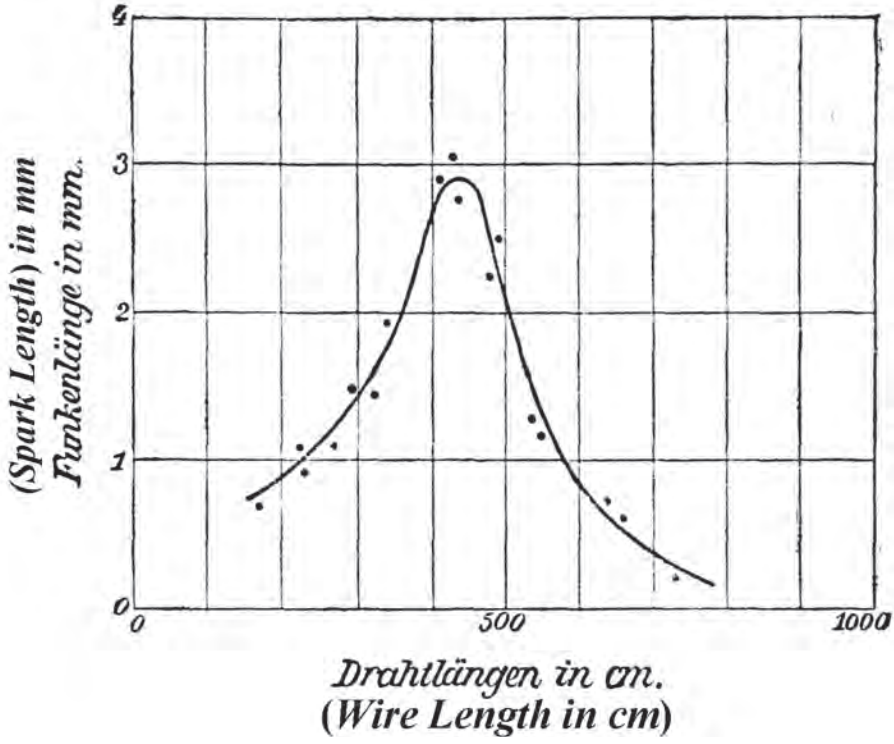


Fig. 11. Hertz discovered that the length of his perimeter wire was approximately equal to the calculated wavelength of his dipole oscillator, thereby concluding that the dipole radiator excited a resonance in the loop. (Hertz, *Electric Waves*, p. 45)

> "There is, as I say, a quantitative relation; and it is a relation which the modern theory of electricity makes known. I cannot go into it here, but I may just say that, very approximately, the wave-length of the electrical oscillation of a discharging jar is 2π times the geometric mean of the static capacity of the jar and the electro-magnetic inertia of the discharger. The capacity of the two gallon jars in series (this being the capacity which gave the best result with 95 feet of leads) was about .002 microfarad, or, say, 1,000 centimetres; hence, supposing the wave length of their discharge through the A knobs to be something like 190 or 200 feet (twice the length of the leads), we should calculate the self-induction of the circuit formed by the jars, short connecting wires, and A knobs, as, something like five metres, which is a reasonable enough value."

To unwind this paragraph, note that Lodge said he observed the "best results" when he used two gallon-sized jars in series with a combined capacity of 0.002 microfarads, but he did not say that he varied the wire length to determine the exact length that produced a local maxima in the response—like the local maxima that Hertz found. Instead, he then "supposed the wavelength" of the standing waves λ was "twice the length of the wires" or λ = 60 meters. Note there is no experimental evidence to support this supposition. Being a Maxwellian, Lodge also calculated the period of the waves on the wire by assuming the wave speed was equal to the speed of light, with the result $T_W = \lambda/c = 60\ \text{m}/3{\times}10^8\ \text{m/s} = 0.2\ \mu\text{s}$. Lodge stated that the capacitance of two gallon-sized jars was 0.002 μF, so the only unknown parameter he needed to compute the period of his source T_S was the inductance. Lodge would have read in Hertz's paper that he had independently computed the inductance of his dipole oscillator as a long conducting wire of length ℓ and diameter d using Neumann's equation for inductance $L = 2\ell\{\ln(4\ell/d) - 0.75\}$.[43]

Lodge could have performed a similar calculation by modeling the inductance of the tank circuit of his source as a circular loop, but Lodge instead decided to use a convoluted approach in which he equated the two periods, $T_S = T_W$, and calculated the inductance of his source that would be required to make the two periods equal. He used the expression $T_S = 2\pi\sqrt{(LC)}$ for the period of his source and the capacitance C = 0.002 μF of his Leyden jars to solve for the inductance. He then "evaluated" the resulting inductance to determine if it was "reasonable." Lodge concluded his inductance was "reasonable enough," although he never provided any criteria for stating why his inductance was reasonable enough.

Suffice it to say that Lodge claiming the inductance was "reasonable enough" is not the same thing as calculating the actual inductance or confirming that the actual wavelength on the wires was 60 meters. There is some latitude in a "reasonable range" of the inductance of his electrostatic machine configuration with Leyden jars, but there is only one actual value for the inductance and

period of his source and one actual fundamental resonant wavelength for his 30 meter wires, none of which he observed, measured, or calculated. To put it another way, the inductance can be in a reasonable range without being exactly right to produce a resonance. Resonances are produced by a fairly precise frequency, not just any frequency within a wide range.

At best, Lodge's approach was qualitative, and it certainly did not demonstrate that he observed standing waves on the wires of his recoil kick experiment. The biggest assumptions Lodge made without any justification were:

- The capacitance of 0.002 microfarad, chosen without varying the wire length, serendipitously produced standing waves,
- The standing waves (assuming standing waves were actually produced) corresponded to the fundamental harmonic of a half-wavelength resonance—consistent with the Melde string experiment—instead of a different harmonic or a different fundamental wavelength, such as a quarter wavelength, and
- The inductance Lodge calculated was in a range to be "reasonable enough," not "precise enough," to produce a resonance.

Lodge's calculations are difficult to follow because he used the CGS system of units, which are not familiar to many. For readers who are interested, I have repeated Lodge's calculations using the MKS system, step by step as he outlined them, in the accompanying Sidebar

Lodge's Calculation Using the MKS System

- The period of the wave on the wires T_W was determined from the well-known relationship $\lambda f = c$, which can be rearranged as follows: $T_W = 1/f = \lambda/c$, where λ is the full wavelength of the resonant wire (60 meters) and $c = 3 \times 10^8$ m/s. The period of the resonance of the wire (assuming the velocity is the speed of light) is $T_W = 2\text{x}10^{-7}$ seconds.
- The period of the source T_S is determined from the well-known expression for the resonance of an LC circuit: $T_S = 2\pi\sqrt{LC}$. This equation can be arranged such that the expression for the inductance of the source becomes $L = (T_S/2\pi)^2/C$.
- The inductance $L = (T_S/2\pi)^2/C$ can be determined by assuming the period of the source T_S is equal to the period of the wave on the wire $T_S = T_W = 2\text{x}10^{-7}$ s, and using the capacitance of the two Leyden jars in series as the source capacitance $C = 2$ nF. The resulting value for the inductance is $L = 5\text{x}10^{-7}$ H.
- Lodge used the CGS system in his calculations for the inductance, with the result that the inductance for his disruptive source came out to be 5 meters. To convert 5 meters of inductance in the CGS system to henries in the MKS system, there are 10^9 cm per henry. Thus, the inductance of 5 meters in the MKS system is (500 cm) x (1 H/10^9 cm) = $5\text{x}10^{-7}$ H or 0.5 μH. Both calculations end up with exactly the same result.

entitled "Lodge's Calculation Using the MKS System," and the inductance thus calculated is identical to Lodge's result.

The various parameters used in Lodge's calculation of inductance are summarized in Table 4. The parameters appearing at the top of the table are the input parameters to the calculation and the assumptions, while the remaining entries are the results of his calculation. Lodge's calculation was based on his assumption that the period of the source T_S was equal to the period of the waves on the wires T_W, which he had *presumed* to exist ($T_S = T_W$). However, this is actually what Lodge was trying to prove, so his calculation is actually meaningless because he has no way of knowing if the inductance is "reasonable." Based on Lodge's assumptions and calculations, the inductance of his source needed to make the two periods equal was 0.5 μH, and the frequency of his source was 5 MHz. In the next section, an independent calculation of the source inductance will be made along the lines of Hertz's analysis as outlined in his 1897 paper, and the

Table 4. Lodge's calculation of inductance.

Parameters	Lodge's Calculation (June 22, 1888)
Capacitance C of two gallon-sized Leyden jars in series	$C = 0.002$ μF
Wire length, $\ell = 95$ feet (30 m)	$\ell = 30$ m
Presumed half-wavelength resonance on wire pair, $\lambda_W = 2\ell$	$\lambda_W = 60$ m
Assumed wave speed $v = c$	$c = 3 \times 10^8$ m/s
Period of waves on wires	$T_W = \lambda_W/c = 0.2$ μs
Other Assumptions	$T_S = T_W$
Calculated source inductance L	$L = (T_S/2\pi)^2/C^*$ $= 0.5$ μH $T_S = T_W = 0.2$ μs $C = 0.002$ μF
Comments on the size of Lodge's computed inductance L	"Reasonable enough"
Wave period T_W	$T_W = \lambda_W/c = 0.2$ μs
Source period T_S	$T_S = T_W = 0.2$ μs
Source wavelength λ_S	$\lambda_S = cT_S = 60$ m
Wire wavelength λ_W	$\lambda_W = cT_W = 60$ m
Source frequency $f = 1/T_S$	5 MHz

*Solving for L using $T_S = 2\pi\sqrt{LC}$

result of that calculation will be compared with the results of Lodge's calculations as it appears in Table 4. It will become clear that Lodge's calculation was specious.

Author's Analysis of Lodge's Recoil Kick Experiment

The author's analysis follows the approach taken by Hertz, who calculated the inductance and capacitance of his source based on the physical parameters of his apparatus, as opposed to Lodge's approach that assumed the period of the waves on the wires was equal to the period of the source, and then judged if the resulting inductance to make the periods equal was "reasonable." A separate determination of the two periods based on the physical parameters of the source configuration would answer the question of whether the inductance was reasonable. To that end, it is necessary to go into some detail about the physical characteristics of Lodge's experiment based on his descriptions of the source and parallel wires in several published documents.

Lodge's Source Description: The basic tank circuit of Lodge's discharge source consisted of the following components that are identified in Fig. 12:

1) two rods holding the discharge knobs, which are shorted together to form a single rod by the arc discharge at point A,
2) two rods, one on each of the two Leyden jars that extend downward from the top knob to the foil at the bottom of each jar,
3) two wires that connect the two Leyden jars to the two discharge knobs, and
4) a metallic foil sheet to connect the outside of the two Leyden jars together in series with a low-inductance path.

Lodge claimed he used a Voss electrostatic machine for this experiment, which he described elsewhere as "a small single-pair-of-plates Voss machine, 18 inches in diameter."[44] A typical Voss machine of the day is shown in Fig. 13.[45] The difference between the machine shown in this figure and the machine Lodge described is that Lodge replaced the two small Leyden jars that came with the Voss machine with two very large gallon-sized jars, which Lodge described as having a diameter of 13 cm and a height of 40 cm.

Lodge claimed that he purchased a quantity of apparatus from a local firm in Chemnitz, Germany, "exceptionally well

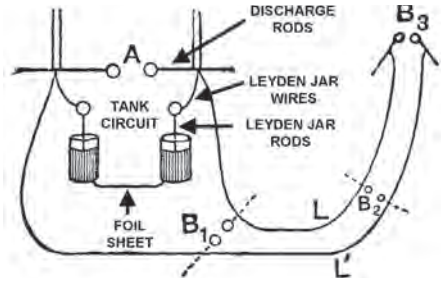


Fig. 12. The tank circuit constituting Lodge's source for his recoil kick experiment consisted of a closed loop with two discharge rods that held the primary discharge knobs A, two Leyden jars with wires to connect to the rods, two Leyden jar rods, and a low-impedance foil connecting the conducting bases of the two Leyden jars. (*J. Soc. Arts*, Vol. 36, p. 880, modified)

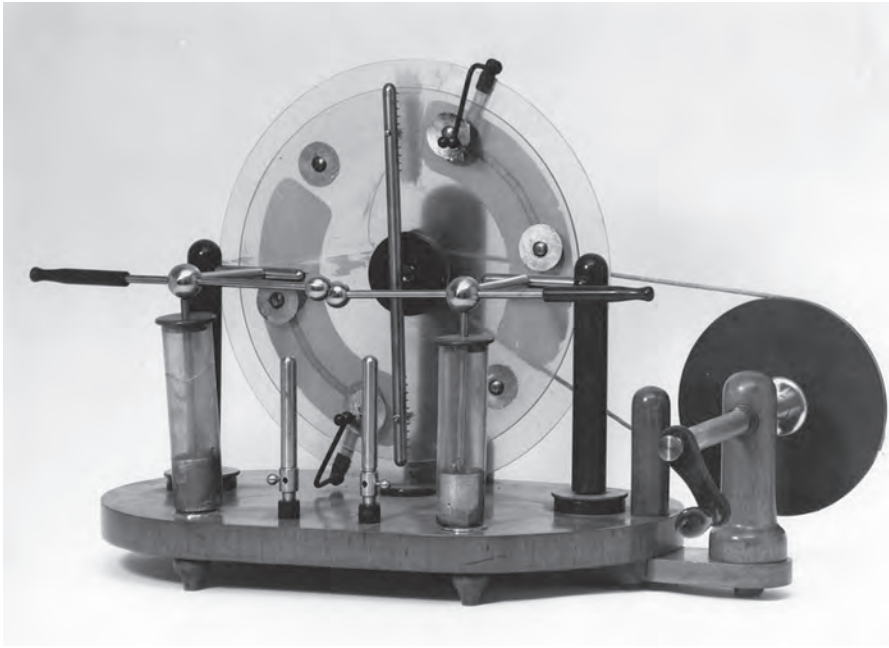


Fig. 13. A typical Voss influence machine dating to 1890, similar to the one Lodge used in his recoil kick experiment. (National Museum of American History, Catalog No. 315900)

made, with no chains, wooden lids, and other gimmicks."[46] An example of such a 40 cm Leyden jar manufactured by Max Kohl in Chemnitz at the turn of the century is shown in Fig. 14. The rod of the jar extends the full 40 cm from the bottom of the jar to the knob at the top where the connection was made to the Voss machine. The jars were so large that they were set on a table in front of the machine on a foil sheet that connected the outside of the jars together.

By scaling the dimensions of the discharge rods in the figure, it appears that the total length between the vertical posts supporting the two rods with the discharge knobs at the ends of each are approximately

Fig. 14. An example of a 40 cm Leyden jar manufactured by Kohl in Chemnitz, Germany at the turn of the century, similar to the ones Lodge purchased in Chemnitz for his lightning experiments. (Max Kohl, Chemnitz, Germany, *Appareils de Physique*, Catalog No. 50, Vol. II and III, c. 1911, p. 831)

13 inches or 33 cm. This length assumes that the rods are short-circuited by the spark discharge during the formation of the standing waves (it was well known that the resistance of a spark discharge was less than a few ohms).

The length of the wires connecting the rods of the jars to the rods holding the discharge knobs on the machine can be estimated by the size of the jars and the recess of the discharge rods from the front of the base upon which the Voss machine is mounted. Since the diameter of the jars were 13 cm and the supports holding on the rods were recessed on the Voss machine board by at least a few centimeters, the length of each wire must have been at least 20 cm. Lodge listed the dimension of the rods and wires he used on his machine in a separate publication,[47] which are listed in Table 5 along with the other key dimensions. The combined total length of the segments in the tank circuit of the source is 180 cm, and diameter of a circular loop with the circumference of 180 cm is 57 cm.

There is no simple method of making an accurate calculation of the inductance of Lodge's Voss machine that has different types of conducting rods and wires with widely varying lengths, angles, and diameters. However, a reasonably accurate estimate of the inductance can be made by modeling the single closed conducting circuit as a circular loop with a circumference equal to the length of the segments forming the tank circuit. Even that calculation is not straightforward because of the widely disparate diameters of the conducting rods and wires, which range from 1 mm wires to a 9 mm diameter discharge rod, not to mention the flat foil sheet used to connect the two Leyden jars together. However, bounds can be put on the range of inductances by making calculations for each of the conductor diameters to determine the sensitivity and bounds on the inductances as a result of the different diameters. The expression used by the author for the calculation of the loop inductances is $L = \mu_0 D/2\{\ln(8D/d) - 2\}$, where L is the inductance in henries, D is the diameter of the loop with a circumference of 180 cm and d is the diameter of the conductor forming the loop.[48] The results of these calculations are shown in Table 6 for the three conductor diameters of Lodge's Voss machine (1 mm, 6 mm, and 9 mm). The upper bound on the inductance is 2.3 μH and the lower bound is 1.5 μH.

Note that the lower bound to the inductance is still a factor of three greater than Lodge's calculation. For purposes

Table 5. Dimensions of the individual components in the tank circuit of Lodge's Voss machine.

Conducting Segments	Diameter	Total Length (cm)	Inductance
Leyden jar rods (2)	9.8 mm	80 cm	0.81 μH
Discharge knob rod (1)	6 mm	34 cm	0.32 μH
# 18 wires (2)	1 mm	20 cm	0.24 μH
	Total	134 cm	1.5 μH

of this analysis, it will be assumed that the inductance of his Voss machine is 1.5 μH, the lowest possible inductance associated with this model.

Table 6. Bounds for the inductance of Lodge's Voss machine tank circuit.

Wire Dia.	Loop Dia.	Inductance
1 mm	57 cm	2.3 μH
6 mm	57 cm	1.7 μH
9 mm	57 cm	1.5 μH

Estimate of the Source Period, Frequency, and Wavelength: The period, frequency, and wavelength of Lodge's Voss electrostatic machine using two gallon-sized Leyden jars can now be made using the author's calculation of the source inductance. In addition, two of Lodge's basic assumptions were also used in this calculation: 1) Lodge claimed he observed the wavelength of the standing waves on his 30 meter wires to be 60 meters, and 2) he assumed, a priori, that the speed of the waves on the wires was equal to the speed of light. The only difference in the author's calculation and Lodge's calculation is that the author calculated the period of the source, $T_S = 2\pi\sqrt{(LC)}$, using the capacitance of the two Leyden jars in series and the author's calculation of the inductance of the source, whereas Lodge assumed the period of the source was equal to the period of the waves on the wire and he calculated the resulting inductance to make it so. In essence, Lodge assumed what he was trying to prove.

The results of the author's calculations are compared with the results of Lodge's calculations in Table 7. The shaded rows in this table highlight the differences in the results of the two calculations. The author calculated the period of Lodge's source by estimating the inductance of the source from physical parameters of the source. As a result, the calculated period of the source was 0.34 μs, which corresponds to a wavelength of 102 meters. According to this calculation, Lodge's source wavelength was much longer than the 60 meter standing waves that Lodge claimed he had observed and measured. It is well known that if the source wavelength is longer than the primary resonance of a transmission line, it will not excite standing waves on the line.

It turns out that Lodge made a very similar calculation to the author's calculation for the inductance of a different source with a rectangular or square source configuration two years later in 1891. He modeled the source as a circular loop as follows:

> "I am not prepared to calculate the inductance of this rectangle precisely, but when approximately square it makes but little difference whether I reckon it as a pair of parallel wires of length u, distance 50, and diameter 0.15, plus a pair of parallel rods of length 50, distance u, and diameter 0.8; or whether I reckon it as a *circle of perimeter* [emphasis added] 2 (50+u) and average [conductor] thickness 0.3."[49]

Clearly, Lodge knew how to make estimates of the inductance of various electrical configurations by using known

Table 7. Comparison of Lodge's calculation with the author's calculation.

Parameters	Lodge's Calculation (June 22, 1888)	Author's Calculation
Capacitance C of two gallon-sized Leyden jars in series	$C = 0.002$ μF	$C = 0.002$ μF
Wire length, $\ell = 95$ feet (30 m)	$\ell = 30$ m	$\ell = 30$ m
Presumed half-wavelength resonance on wire pair, $\lambda_W = 2\ell$	$\lambda_W = 60$ m	$\lambda_W = 60$ m
Assumed wave speed $v = c$	$c = 3 \times 10^8$ m/s	$c = 3 \times 10^8$ m/s
Period of waves on wires	$T_W = \lambda_W/c = 0.2$ μs	$T_W = \lambda_W/c = 0.2$ μs
Other Assumptions	$T_S = T_W$	T_S may or may not $= T_W$
Calculated source inductance L	$L = (T_S/2\pi)^2/C^*$ $= 0.5$ μH $T_S = T_W = 0.2$ μs $C = 0.002$ μF	$L = \mu_0 D/2\{\ln(8D/d) - 2)\}$ $= 1.5$ μH $D = 57$ cm, $d = 9$ mm $C = 0.002$ μF
Comments on the size of Lodge's computed inductance L	"Reasonable enough"	Lodge's inductance of 0.5 μH is 3 times too small
Wire wave period T_W ($v = c$)	$T_W = \lambda_W/c = 0.2$ μs	$T_W = \lambda_W/c = 0.2$ μs
Source period T_S	$T_S = T_W = 0.2$ μs	$T_S = 2\pi\sqrt{LC} = .34$ μs
Wire wavelength λ_W	$\lambda_W = cT_W = 60$ m	$\lambda_W = cT_W = 60$ m
Source wavelength λ_S	$\lambda_S = cT_S = 60$ m	$\lambda_S = cT_S = 102$ m
Source frequency $f_S = 1/T_S$	$f_S = 5$ MHz	$f_S = 2.9$ MHz

*Solving for L using $T_S = 2\pi\sqrt{LC}$

inductance models of the day. It is my opinion that Lodge actually made a similar calculation in his 1888 paper for the recoil kick experiment, but he did not like the answer. He then reversed the process by calculating the inductance necessary to make the period of the source equal to the period of the wires. He was then able to declare the result was a "reasonable value" of inductance—a qualitative statement that none of his peers would likely dispute. In that way he was able to claim that he had discovered standing waves on wires retroactively to March 1888 using the source and wire parameters of his recoil kick experiment. This approach clearly worked for him because none of his peers took exception to his computational approach or the conclusion he drew from it in his paper dated June 22, 1888.

Take Away from Lodge's Paper Published on June 22, 1888

The key point is that Lodge's data did not show any evidence of standing waves, and certainly not "without any thought or scheming at all, [giving] me evidence of the very waves I had been thinking so much about:"

- Lodge's data was not consistent with any known standing wave patterns for an open-circuited transmission line.
- Lodge's data showing a doubling at the end of the line over the input voltage was consistent with a reflection in the absence of a resonance.

- Lodge's recoil kick configuration was incapable of identifying nulls or characterizing standing waves.
- Lodge's characterized optical signatures (glows or brush discharges) as being limited to the far end of the wires, signatures which were inconsistent with his claims of observing a half-wavelength resonance. A half-wavelength resonance on wires with an open circuit at the end must have a voltage at the source equal to the voltage at the end.
- In Lodge's convoluted calculation to demonstrate that his source produced a half-wavelength standing wave on his 30 meter wires, he actually assumed, a priori, that the wavelength of his source was equal to the wavelength of the standing waves he observed; in essence, he proved what he assumed.

Lodge Proposed an Application for his Recoil Kick Experiment (July 7, 1888)

Lodge submitted a second paper entitled "On the Theory of Lightning Conductors" dated July 7, 1888, for publication in the August issue of *Philosophical Magazine*. The main purpose of this paper was to provide the theoretical basis for several of the lightning experiments that Lodge had described at the Mann lecture. However, there was a section entitled "Experiment of the Recoil Kick" that consisted of approximately four pages of text with several subjects that had virtually nothing to do with lightning conductors or even the general subject of lightning. The main purpose for these four pages was apparently to allow Lodge a timely publication describing a new application for his recoil kick experiment.

Why Lodge would add these four pages to a paper with an unrelated subject and title was something of a mystery, but fortunately Lodge saw fit to comment on this material in his book *Advancing Science* published many years later in 1931. The following comments appeared in several paragraphs of his book under the title "Supplementary Remarks on Waves:"

> "I will also reproduce the concluding part of my paper published in 'The Philosophical Magazine' in that same month, August 1888, *though it ought to have appeared in July*. It represented work done earlier in the year, before that which was communicated to the [British] Association. All this sounds complicated, but in those days *months were important*. I was thoroughly imbued with the notion of electric waves from the beginning. Hertz was not. Hertz had splendid opportunities for experiment, in the large premises in Karlsruhe, and, moreover, he had great mathematical facility, besides *a strong scientific instinct and quickness of apprehension*."[50]

Lodge conveyed three points in the phrases cited above that are highlighted by the added italics. First, he said he intended to publish the paper in the July issue of the *Philosophical Magazine*, but it was delayed until the August issue—almost surely because he decided to add the concluding pages that had nothing

to do with lightning conductors. Second, Lodge said the concluding pages described work done before the work he had submitted to the British Association. That may well be, but there is overwhelming evidence from the content of the last few pages that it was also performed *after* Lodge read Hertz's paper. This evidence will be presented in due course in a section entitled "*Lodge Opined on How Much Shorter Waves Could Be Made*." Third, Lodge said, "all this sounds complicated, but in those days months were important." What he meant was that science was advancing rapidly and publication dates were critical, especially when it came to Hertz, who Lodge said "had a strong scientific instinct and *quickness of apprehension*." The fact that Lodge connected Hertz's name with these pages in his August paper is further evidence that Lodge was aware of the progression of Hertz's work when he wrote those pages.

Lodge wanted to publish his new concept as soon as possible because he was concerned about how fast Hertz was progressing in the discoveries associated with resonance, standing waves, the invention of a new method of generating short electromagnetic waves with wavelengths of less than 10 meters, and the ultimate goal of finding electromagnetic waves in free space. Lodge surely recalled FitzGerald's pronouncement at the Southport meeting of the British Association in 1883 regarding the generation of electromagnetic waves that Maxwell predicted: "It would be possible to produce waves of as little as ten metres wave-length, or even less."

In fact, the common theme in the last section of this paper was the generation and application of very short waves of less than 60 meters. The very short waves that Lodge referred to in his paper would have had no application to Lodge's lightning research because Lodge believed the majority of the energy content of lightning was between 100 kHz and 1 MHz (3,000 to 300 meters or longer).[51] Evidence that Lodge was interested in very short wavelengths actually appeared in a footnote to the recoil kick experiment in Lodge's previous publication in the *Journal of the Society of Arts*:

> "Since the delivery of the lecture [to the Society of Arts in March 1888] a great number of quantitative observations along these lines have been made. Evidence of electro-magnetic waves 30 yards long have been obtained. I expect to get them still shorter."[52]

Lodge Proposed a Method to Determine the Frequency of an Oscillating Source

Lodge introduced the last section of this paper entitled "Experiment of the Recoil Kick" with the following words:

> "Among other experiments described in the lectures above mentioned are some which appear to be of considerable theoretical interest, wherein a recoil kick is observed at the ends of long wires attached by one end to a discharging condenser circuit."

This statement was accompanied by the circuit configuration shown in

Fig. 15, which was slightly different from that of his earlier recoil kick configuration. This configuration used only one Leyden jar and eliminated the electrostatic machine used to charge the Leyden jar to the point of discharging the knob at A. Lodge then went on to explain how this new concept would work:

> "The pulses rush along the surface of the wires, with a certain amount of dissipation; and are reflected at the distant ends; producing the observed recoil kick at B. They continue to oscillate to and fro until damped out of existence…the best effect should be observed when each wire is half a wave-length, or some multiple of half a wave-length, long. The natural period of oscillation in the wires will then agree with the oscillation period of the discharging circuit, and the two will vibrate in unison.
>
> "Hence we have a means of determining experimentally the wave-length of a given discharging circuit. Either vary the size of the A circuit, or adjust the length of the B wires, until the recoil spark B is as long as possible."[53]

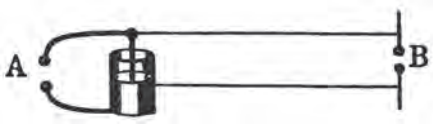


Fig. 15. Lodge proposed a method of determining the frequency of an unknown source by varying the length of the wires attached to it, finding the length of the wires that produced the maximum response at the end, and then assuming that the source wavelength was equal to twice the length of the wire. (*Phil*. Mag., Vol. 26, p. 227)

Lodge did not say how he intended to charge and discharge the Leyden jars. Perhaps this configuration represented a simplified circuit for purposes of explanation, because towards the end of this section he commented that an electrostatic machine or an induction coil could be used to create a succession of pulses that might be needed to make the necessary measurements possible.

Lodge's Proposed Approach had Fundamental Problems

Lodge stated that the only parameter necessary to determine the wavelength of a resonance was the magnitude of response at the open end of the wires (at point B), which could be found by varying either the wire length or the size of the source (i.e., source frequency/wavelength). Lodge also stated that the largest response "should he observed when each wire is half a wave-length, or some multiple of half a wave-length, long," but he did not state how to determine which harmonic produced the largest response. The wavelength that produces the largest response cannot be determined without identifying the correct harmonic. What happens if the amplitudes of two adjacent harmonics are approximately equal?

In most cases the lower order harmonic responses of resonant circuits have greater amplitudes than higher order harmonics, and Lodge did assume that the largest response was produced by the primary resonance (i.e., the first harmonic) in his recoil kick experiment. Unfortunately, Lodge also assumed that the fundamental resonance was a half-wavelength resonance, when in fact, the

primary resonance for a transmission line with an open circuit at the far end is a quarter wavelength. This assumption virtually assured that he came up with the wrong resonant frequency for his transmission line.

Also inherent in Lodge's proposal was the assumption that resonant responses would have amplitudes measurably greater than double the applied voltage, which can be produced by the reflection of a wave from an open-circuit at the end of a transmission line—even in the absence of standing waves. In fact, the response at the open end of the wires from Lodge's recoil kick experiment was just about a factor of two above the applied voltage—about the same as the magnitude expected from a non-resonant response.

Lodge's Analysis of Standing Waves on Wires Missed the Mark

After introducing his new measurement technique, Lodge produced several pages of equations to provide the theoretical basis for his recoil kick experiment. Lodge began by stating: "The propagation of these oscillatory disturbances along the wires goes on according to the following laws…" He then introduced two partial differential equations collectively known as the wave equation, and explained: "It will give stationary waves in finite wires of suitable length, supplied with an alternating impressed E.M.F." There are an infinite number of solutions to the wave equation, but the general solution has the form $V(x,t) = f_1(x - vt) + f_2(x + vt)$, where v is the velocity of the wave and the functions f_1 *and* f_2 represent waves moving in *opposite* directions on the line. The actual solutions of interest depend on the initial conditions and boundary conditions.

Lodge claimed he used a solution for a "long wire" and "for the case where the resistance of the wires was small and the frequency was large:"

$$V = V_0 \exp[-(x/v)/\tau)] \cos n(t\text{-}x/v) \Rightarrow V_0 \cos n(t\text{-}x/v).$$

For the case where the resistance of the wires is small and the frequency is large, the time constant τ in the exponential was large relative to x/v, so the steady-state standing waves, if any, would have formed before there was a significant energy loss due to the resistance of the wires. Thus, the exponential term is essentially unity for the times and lengths of interest.

However, Lodge's solution is problematic because it has the form for a wave traveling in one direction only, and therefore it does not account for reflections, which would be necessary to produce standing waves. A wave moving in one direction only might be appropriate for sinusoidal waves on an ideal transmission line where the wires are much longer than the wavelength of the sinusoidal forcing function, or perhaps a wire of any length when the load at the end of the line is matched to the transmission line. In both cases reflections from the far end are no of consequence. Furthermore, Lodge did not apply any boundary conditions to these equations, so he was unable to determine the allowable modes for standing waves—and in particular,

he did not identify the correct primary harmonic (the lowest order harmonic) of his recoil kick experiment. Instead of identifying a quarter-wavelength resonance as the first harmonic, he erroneously assumed that the first harmonic for his configuration was a half wavelength, apparently assuming that the primary harmonic was the same as that for Melde's vibrating string experiment, to which he referred.

Lodge's theory in this paper for his experiment was not particularly useful, to say the least, although Lodge was apparently proud of his analysis because he referred to it in a later publication: "I worked out the theory of these wire-guided waves (see "The Philosophical Magazine" for August 1888, p. 217)."[54] The solution Lodge used was the same one Oliver Heaviside used to determine the best characteristics for a transmission line to minimize the degradation in the pulse characteristics for long marine cables where the termination impedances and standing waves were not relevant.

Calculation of Standing Waves on Open-Circuit Transmission Lines

The solutions of interest for Lodge's configuration are the steady-state solutions describing standing waves produced by sinusoidal excitations on an ideal lossless transmission line of length L, where waves are reflected from an open circuit at the far end. The source impedance (and the losses in the wires) will determine the amplitude of the allowable resonances. The following equations represent the possible wavelengths for standing waves on two wires of length L with an open circuit at the end. In the following equations, the wave number is defined as $k = 2\pi/\lambda$, and λ represents the possible wavelengths for standing waves on a line of length L:[55]

$$V = V_0 (\sin (kx - \omega t) + \sin(kx + \omega t)) = 2V_0 \sin(kx) \cos(\omega t), \text{ and}$$
$$V = V_0 (\cos (kx - \omega t) + \cos(kx + \omega t)) = 2V_0 \cos(kx) \cos(\omega t).$$

The first equation with $\sin(kx)$ describes the envelope of a standing wave for the case where the amplitude of a standing wave is null at the input to the transmission line and maximum at the open end. This solution is applicable to a transmission line length L that is equal to a quarter wavelength or an odd multiple of its length: $L = \lambda/4, 3\lambda/4, 5\lambda/4$, etc. A solution with the signal being null at the input to a transmission line may be counterintuitive, but in the case of a quarter-wavelength line a signal travels down the line, where it is reflected, and returns from the open end in half a period—just at the time when a harmonic source has the same amplitude but with a reversed sign such that the two signals exactly cancel. This is the solution that Lodge missed by assuming the fundamental harmonic was a half wavelength.

The second equation with $\cos(kx)$ describes the envelope of a standing wave for the case where the amplitude of the standing wave is maximum at both the input to the line and the open end. The line length L is equal to a half wavelength or a multiple of its length: $L = \lambda/2, 2\lambda/2, 3\lambda/2, 4\lambda/2$, etc. The spatial envelopes for

these two solutions are shown graphically in Fig. 16.

Without realizing that there was a solution with a quarter-wavelength standing wave, Lodge could not correctly determine or predict standing wavelengths using the response data from his recoil kick experiment. Lodge himself stated that he looked for the largest signal at the open end of the line, and he assumed it was a half-wavelength solution. It could just as easily have been a standing wave corresponding to a quarter wavelength, or a harmonic thereof such as a three-quarter wavelength—or simply a reflection of a sine wave with a wavelength that was too long to produce standing waves.

It should be noted that very few historians, if any, have pointed out that Lodge was in error by assuming that the fundamental resonance of a transmission line with an open end was a half wavelength. Aitken actually perpetuated

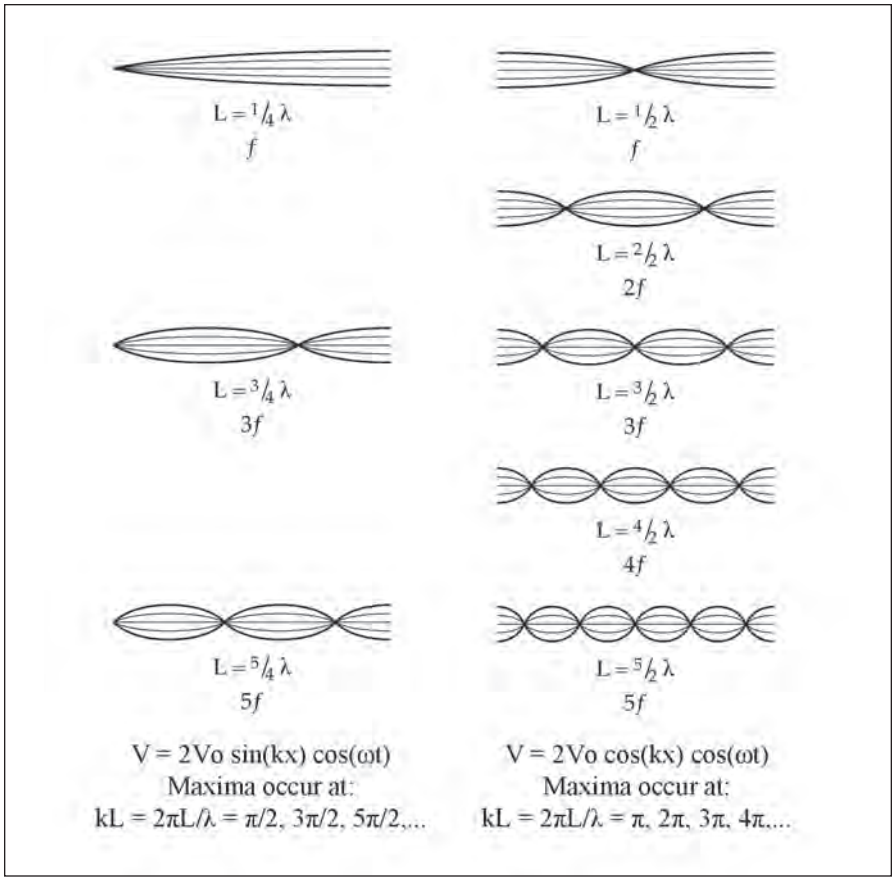


Fig. 16. This graphical representation represents the possibilities for the first few harmonics of standing waves possible for a transmission line with an open circuit at the far end. (Glen Elert, *The Physics Hypertextbook*, https://physics.info/waves-standing/)

this error by stating: "The wires he was using in this first [recoil kick] experiment were each 95 feet in length, indicating a resonant frequency of about 5 MHz." A transmission line 95 feet (30 meters) long is resonant at a quarter wavelength, which is 120 meters or 2.5 MHz, or some harmonic thereof. Since the resonant frequency of a transmission line is generally characterized by its first, or fundamental harmonic, the frequency of 5 MHz that Aitken cited for Lodge's wires was actually the second harmonic.

Hertz's Approach Compared to Lodge's Approach

Hertz never had to deal with the wave equation or analyses of any kind to determine the wavelength of the resonant response caused by his dipole source because unlike Lodge, he was able to measure the loops and nodes directly with his resonant loops. Referring to the figure in the sidebar entitled "Hertz's Calculation of Wave Speed on Wires," Hertz used a single long wire for this experiment, which was grounded at the far end by a short circuit, such that the return current was through the ground. He used his resonant loops to map out the "loops and nodes" of the standing waves, which he discovered by varying the length of the wire until he found measurable resonances. In the example cited in the sidebar, Hertz measured the same distance between two adjacent nodes (2.8 meters) for two different lengths of wire (5.5 and 8 meters).

Since Hertz actually mapped out the nodes of the resonant responses, he did not need to know the specific harmonic, although he could have also measured that as well. A measurement of the distance between adjacent nodes was the most accurate means of determining a half wavelength because rate of change of the amplitude with respect to distance on the wires is greatest at the nodes and least at the antinodes.

Lodge Opined on How Much Shorter Waves Could Be Made

The discussion of Lodge's August 1888 paper would not be complete without describing Lodge's thoughts on how short it was practically possible to generate electromagnetic waves. Lodge's thought on this subject appeared in the last few pages of his August 1888 paper, but it had nothing do to do with the subject of his lightning experiments. His thoughts on short waves provide clear evidence that Lodge read Hertz's 1887 paper before he wrote it. Lodge began this topic without a segue from his proposed approach to measure wavelengths on wires:

> "It is interesting to see how short it is practically possible to make waves of this kind. A coated pane [glass] can be constructed of say two centimetres electrostatic capacity, and, by letting it overflow its edge, a discharge circuit may be provided of only a few centimetres electromagnetic inductance.
>
> "No doubt much shorter waves still may be obtained by discarding the use of any so-called condenser [i.e., Leyden jar], and by causing the charge in a sphere or cylinder to oscillate to and fro between its ends, as might be done by giving it a succession of sparks."[56]

This is the first time Lodge ever mentioned that shorter wavelengths could be generated by discarding Leyden jars and causing the charge to flow to and fro from the ends of a sphere or cylinder. This is exactly what Hertz described in his 1887 paper that Lodge claimed he read sometime before early June 1888. It was Hertz who had invented dipole radiators without condensers (Leyden jars) to which he had attached both spheres and cylinders at the ends of rods with spark discharge knobs at the other ends, thereby producing a succession of sparks that caused the charge in the cylinders or spheres to oscillate to and fro between its ends (see Fig. 17).

Lodge took credit for this "discovery" in his autobiography *Past Years*, where he made this reference to the above quotation appearing in the *Philosophical Magazine*:

> "It must be remembered, however, that we did not then know of the existence of any such waves: we knew about electric oscillations, for Lord Kelvin had given their theory so long ago as 1853, and we were accustomed to demonstrate the oscillating character of the Leyden jar spark in various ways. Still, even in those early days, I understood fairly about the waves, as can be shown by the concluding portion of my paper in the *Philosophical Magazine* for August 1888, pp. 227–30."[57]

The irony here is that it was Hertz who "understood fairly about the waves," not Lodge, who had become aware of this

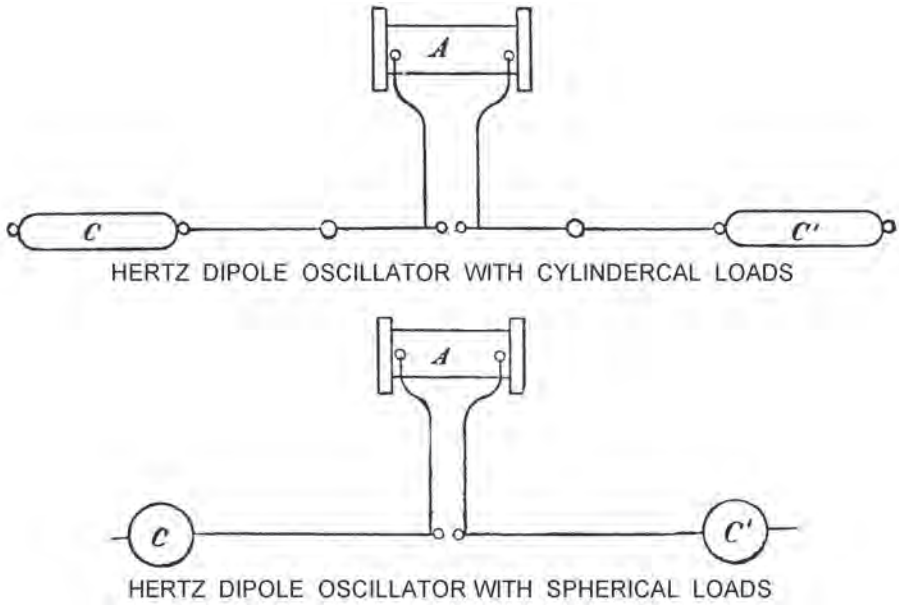


Fig. 17. Hertz used cylindrical and spherical loads to increase the capacitance of his dipole oscillator that was capable of radiating wavelengths shorter than 10 meters. (Hertz, *Electric Waves*, pp. 40, 47)

concept by reading Hertz's 1887 paper. Not only had Lodge read Hertz's paper before Lodge's August 1888 paper was published, but Lodge had read Hertz's paper even before he submitted his June 1888 paper for publication.

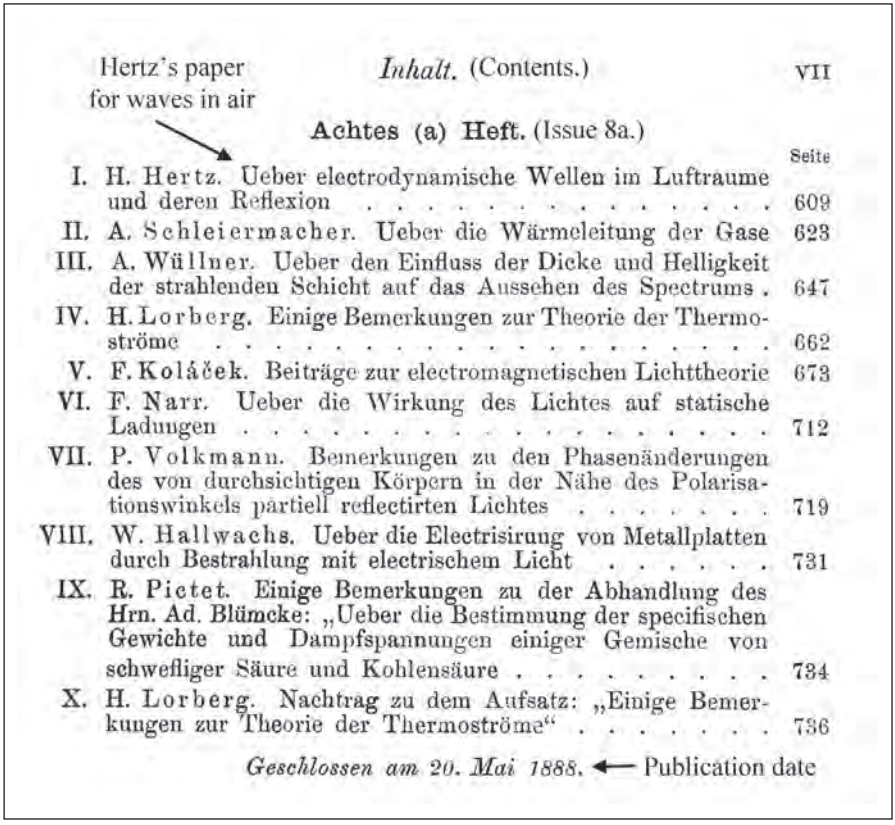
Lodge Claimed he Discovered Ether Waves Predicted by Maxwell (July 24, 1888)

After Lodge submitted his paper for publication in the August issue of the *Philosophical Magazine*, he departed by train for a vacation in Cortina, Italy. According to Lodge, he was on the train to Cortina when he had the opportunity to read the "current July number" of *Annalen der Physik* he took with him, which contained Hertz's article describing his discovery of electromagnetic waves in air. Immediately after reading the article, Lodge wrote a postscript in Cortina dated July 24, 1888, which he sent back to the editor of the *Philosophical Magazine*, asking that it be appended as a postscript to the paper he had submitted just before he left. Lodge wrote the following words in his postscript:

> "I have seen in the current July number of Wiedemann's *Annalen* an article by Dr. Hertz, wherein he establishes the existence and measures the length of æther waves excited by coil discharges; converting them into stationary waves, not by reflection of pulses transmitted along a wire and reflected at its free end, as I have done, but by reflection of waves in free space at the surface of a conducting wall…. The whole subject of electrical radiation seems working itself out splendidly."[58]

This postscript is often cited by historians but rarely has it been analyzed. First, Lodge claimed that Hertz disclosed his discovery of ether waves in the "current July number" of *Annalen der Physik*. That in itself was a deceptive statement. The actual issue in which Hertz disclosed his discovery of stationary waves in air appeared in issue No. 8(a) of Vol. 34, published two months earlier on May 20, 1888 (see Fig. 18). The July issue of *Annalen der Physik* was published as Issue No. 9 on July 15, 1888, which appeared in Vol. 35. The July issue would not have been received in London by the time Lodge departed for Italy. Some historians have been misled by Lodge's wording "the current July number of Wiedemann's *Annalen*," thinking that the paper was actually published in July. For example, Maxwellian historian Bruce Hunt writes that Hertz's paper was "published in July in the *Annalen de Physik* as 'Ueber elektrodynamische Wellen in Luftraume und deren Reflexion'."[59]

Russell Burns is another historian who was misled by Lodge's phrase, "I have seen the current July number of Wiedemann's *Annalen* an article by Hertz…" Burns cited this quotation from Lodge's postscript and followed it with this statement: "Had Lodge's paper been published in an earlier issue of the *Philosophical Magazine*, as he anticipated, his claim to simultaneous discovery of electromagnetic waves would have been greatly strengthened."[60] Indeed, Lodge's postscript was published in the



Hertz's paper for waves in air

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Geschlossen am 20. Mai 1888. ← Publication date

Fig. 18. Lodge claimed that Hertz disclosed his discovery of waves in air in the "current July number" of *Annalen der Physik*, but the actual issue in which it appeared was No. 8(a) of Vol. 34, published two months earlier on May 20, 1888.

August issue of the *Philosophical Magazine*, although Lodge had anticipated publishing it in the July issue. Nevertheless, Burns was incorrect in stating that publishing it in an earlier month as Lodge anticipated (i.e., July) would have strengthened Lodge's claim of discovery, because Hertz had already published his seminal paper on the discovery of waves in air in an issue of *Annalen der Physik* dated two months earlier on May 20, 1888—not the July issue, as Lodge had asserted.

It is apparent that Lodge attempted to move the date of Hertz's discovery of waves in space forward in time to make it appear that he published his paper disclosing the discovery of waves in space at about the same time as Hertz discovered waves in space. In fact he did claim that his work was simultaneous with and independent of Hertz:

> "Experiments on these stationary waves in wires, observation of their nodes and loops, and measurements of their

> wavelength, were going on at Liverpool, simultaneously with, but independently of, the experiments of Hertz in Carlsruhe on waves in space."[61]

Lodge's Claim to the Discovery of Waves on Wires is an Enigma

An enigma that has never been resolved is how Lodge could maintain throughout his life that he, not Hertz, had discovered electromagnetic waves on wires, when in fact Hertz had discovered waves on wires long before Lodge. Lodge first made the claim that he had discovered ether waves on wires in his postscript dated July 24, 1888, immediately after reading Hertz's paper on waves in air. Apparently, Lodge was trying to distance himself from Hertz's work to make it appear that he had done something different from Hertz. And why not? If Lodge admitted that he had merely repeated the same experiments with waves on wires that Hertz had first published on February 9, 1888, there would have been no reason for Lodge to publish his work.

The truth is that Hertz discovered waves on wires long before Lodge, and Hertz transitioned his work from waves on wires to waves in air in an orderly fashion after he documented his discovery of waves on wires in his lab notes on November 7, 1887. The transition to waves in air was completed in March when he documented his discovery of waves in air in a letter to his mentor, Hermann von Helmholtz, dated March 19, 1888, in which he described his discovery: "Electrodynamical waves are reflected from solid conducting walls; at normal incidence the reflected waves interfere with the incident and give rise to standing waves in the air."[62] This citation is taken from a chapter from this reference entitled "On Hertz's Conceptual Conversion: From Wire Waves to Air Waves," which provides a detailed description, based on his laboratory notes, of how he discovered standing waves in air while he was performing experiments with waves on wires.

Whether Lodge was aware that Hertz had discovered waves on wires when he wrote his postscript is debatable, but there can be no doubt that he was aware of it by the time he went to the British Association meeting at Bath in September. It turns out the very first line in Hertz's paper in issue No. 8(a) of *Annalen*, which Lodge claimed he read in July on his way to Cortina, had a footnote citing Hertz's previous article about his discovery of waves on wires entitled "On the Finite Velocity of Propagation of Electromagnetic Actions." The following is a translation of the first sentence of the paper Lodge read about his discovery of waves in air, which contained the footnote citing his previous paper addressing waves on wires:[63]

> "I have recently endeavored to prove by experiment that electromagnetic actions are propagated through air with finite velocity."[64]

The two referenced papers describe Hertz's work on waves on wires. Therefore, there can be little doubt that Lodge knew Hertz had discovered waves on wires and had published the results in

the Berlin Academy journal as early as February 9, 1888, which was later published in the issue of *Annalen der Physik* preceding the one Lodge read on the way to Cortina. Yet, when Lodge presented his paper on how he discovered waves on wires at Bath, he referenced Hertz's work with waves in air but failed to mention Hertz's work on discovering waves on wires. The fact that he did not mention Hertz's work with waves on wires seemed strange enough to an editor of the *Electrician* that he pointed it out in his review of the discussion session that followed Lodge's presentation:

> "The President, after expressing the thanks of the section to Prof. Lodge, said there was a certain amount of difference in the theory of waves propagated by conductors and waves propagated in the non-conductor. Hertz had made experiments, *although Prof. Lodge seemed to have overlooked them* [emphasis added], on the propagation of waves in conductors very much analogous to those of Prof. Lodge, only Hertz worked in a different way, as he observed the reflexion at the end of a wire and the existence of nodes in the length of a wire. He also observed the alterations of induction in the air without any conductor."[65]

This unidentified writer knew of Hertz's work with waves on wires, and it is likely that many in the audience did, as well. As time went on, Lodge became more specific about his assertion that Hertz did not experiment with waves on wires. In Lodge's book *Advancing Science* published in 1931 he wrote, "He [Hertz] reflected the waves into stationary waves, and detected nodes and loops so formed, but he used no wires to guide them."[66] Lodge was very specific that Hertz had not used wires, and at no place in this book did Lodge disclose that Hertz had used wires. In his autobiography published in 1932, Lodge made the same statement that he had made forty years before in 1888:

> "He [Hertz] found the evidence of the waves on the same principle as I had found them, by the nodes and loops which were produced by the interference of the direct and reflected pulses; but he found them in space, instead of along wires."[67]

Perhaps the only time that Lodge acknowledged that Hertz had worked with waves on wires was in 1892 when he marginalized Hertz's work in the following statement:

> "I had also measured wave-length by an interference method, but had only worked with the waves along wires, whereas Hertz had worked in free air. Hertz had also worked on wires to some extent either then [referring to July 1888] or later, and found an apparent discrepancy between the velocity along wire and the velocity in air."[68]

Lodge's comment that Hertz had worked on wires to some extent in July 1888 is quite misleading. The truth is that Lodge's experiments with waves on wires were not unique and were not

performed simultaneously with Hertz's experiments. Hertz began his work with waves on wires in 1886 and first published his discovery of standing waves on wires that were resonant with his dipole source on May 15, 1887, long before Lodge ever began his experiments on the recoil kick experiment, which he claimed began on March 1, 1888. Hertz recorded the loops and nodes of resonances on long wires on November 7, 1887, and he used the data to calculate the velocity of waves on wire, which was first published on February 9, 1888, before Lodge performed his first recoil kick experiment (see first sidebar "Hertz's Calculation of Wave Speed on Wires").

In making his claim of discovery of ether waves predicted by observing standing waves on wires, there are four critical points that Lodge did not disclose:

- Lodge was not the first to discover standing waves on wires. Lodge was aware that both Hertz and Bezold had already observed standing waves on wires by May 1887,
- Hertz had measured standing wave on wires, calculated the speed of waves on wires, and published the results on February 9, 1887, and again on May 15, 1888, in *Annalen der Physik*,
- Lodge did not actually measure standing waves on wires by observing loops and nodes; he inferred the wavelength from a single measurement (by erroneously assuming the standing wave was a half wavelength), and
- Standing waves on wires are not the same as ether waves (waves in free space).

In the end, Lodge wrote his postscript immediately after reading Hertz's paper. Hertz's discovery of standing waves in air had become Lodge's epiphany for claiming his discovery of standing waves on wires.

Lodge Disclosed his Discovery of Ether Waves to the British Association (September 1888)

Lodge wrote that he went to the meeting of the British Association in Bath believing he had discovered waves predicted by Maxwell: "I went to the meeting full of what I thought was the discovery of Maxwell's waves, which I had produced by FitzGerald's method of electrical oscillation, and had found means of detecting by reflecting them back on themselves, so that they formed stationary waves and exhibited themselves by nodes and loops."[69] Before he went, he had submitted abstracts for two papers, one entitled "On the Measurement of the Length of Electro-magnetic Waves" and the other entitled "On the Impedance of Conductors to Leyden-jar Discharges."[70] Both papers were to be presented in Section A: Mathematical and Physical Science, but before this section opened for papers on September 6, 1888, the section chairman, George FitzGerald, gave his now famous speech introducing the recent findings of electromagnetic waves in air by Hertz. FitzGerald's speech will be recounted first, followed by an account of Lodge's paper on the measurement of standing waves, which he gave the next day on September 7, 1888.

FitzGerald Announces Hertz's Discovery of Maxwell's Waves at Bath (Sept. 6, 1888)

The word of Hertz's discovery had actually reached FitzGerald in early June 1888, as evidenced by correspondence from FitzGerald to Hertz dated June 8, 1888. The opening line of FitzGerald's letter explains how he heard of Hertz's results: "I saw the other day that Prof. Helmholtz announced your splendid verification of Maxwell's theory."[71] The purpose of the correspondence dated June 8 was a request for a copy of Hertz's latest paper describing his discovery of the electromagnetic waves predicted by Maxwell, which was published by *Annalen der Physik* in No. 8(a), Vol. 34, issued on May 20, 1888. Clearly, FitzGerald had not received the latest issue of *Annalen* at the time he wrote the letter.

FitzGerald also praised Hertz for his work in this letter:

> "I consider that no more important experiment has been made in this century.… Your experiment will be called 'Hertz's classical experiment' that decided between theories of electrodynamic action at a distance and by means of the ether [i.e., ether waves, meaning electromagnetic radiation in space]."[72]

He closed the letter with these words: "Hoping to receive your invaluable paper." Hertz replied three days later by enclosing the papers that had been requested, and he also announced to FitzGerald that he had produced standing waves in air and had measured their wavelength. Hertz's rather lengthy response is reproduced in both German and English. This letter and other correspondence between Hertz and the Maxwellians are reproduced in O'Hara's book entitled *Hertz and the Maxwellians,* which is cited in endnote 71.

Armed with the information Hertz sent, FitzGerald announced Hertz's discoveries in an address to the Mathematical and Physical Science Section of the British Association meeting at Bath on September 6, 1888. The following three paragraphs documented portions of his speech that contain the critical information on Hertz's discovery. The first of the three paragraphs excerpted from his documented speech made it clear how important he believed Hertz's results were:

> "In a presidential address on the borderlands of the known delivered from this chair the great Clerk Maxwell spoke of an undecided question whether electromagnetic phenomena are due to a direct action at a distance or are due to the action of an intervening medium. The year 1888 will be ever memorable as the year in which this great question has been experimentally decided by Hertz in Germany and, I hope, by others in England. It has been decided in favour of the hypothesis that these actions take place by means of an intervening medium."[73]

A second paragraph excerpted from his speech made it clear that the critical deciding experiment could not involve, in particular, waves on wires, *transmission*

lines, or conducting materials, because waves on these configurations satisfied both the action-at-a-distance theory as well as Maxwell's more general theory:

> "What was wanted was an experiment to decide between the hypothesis of direct action at a distance and of action by means of a medium. At the time that Clerk Maxwell delivered his address no experiment was known that could decide between the two hypotheses. Specific inductive capacity, the action of intervening matter, the delay in telegraphing, the time propagation of electro-magnetic actions by means of conducting material—these were known, but he knew that they could be explained by means of action at a distance, and had been so explained. Waves in a conductor do not necessarily postulate action through a medium such as ether."[74]

As an aside, Lodge later tried to obviate FitzGerald's objection to experiments with "waves in a conductor" by noting that electric waves at high frequencies propagated on the outside of the wire due to skin depth effects, not in the wire, so they are actually ether waves. Lodge's observation was flawed because whether the charge flows in the wire or on the surface of the wire is immaterial; the strong radial electric fields produced by the charge *in or on* the wires were and still are always "in the ether," that is, outside the conductor. FitzGerald's real point was that it was impossible to observe propagating electric fields in a region near a conductor where charge flows, which produces *electrostatic* electric fields exceeding the propagating electric fields in the region near the wire.

A third paragraph excerpted from FitzGerald's speech was very explicit that the *experimentum crucis* (critical deciding experiment) must involve propagating electromagnetic waves, such as the one Hertz performed with ether waves in air—like those demonstrating the interference of light waves:

> "As I have endeavoured to impress upon you, no *experimentum crucis* between the [two] hypotheses is possible except an experiment proving propagation in time either directly, or indirectly by an experiment exhibiting phenomena like those of the interference of light."[75]

Lodge Presents his Paper on the Measurement of Electromagnetic Waves

Lodge gave his presentation entitled "On the Measurement of the Length of Electro-magnetic Waves" the next day, September 7, in which he described his discovery of standing waves on wires. Lodge must have been disappointed at FitzGerald's speech, which focused on the accomplishments of Hertz in finding the elusive ether waves predicted by Maxwell but said nothing about Lodge's observations of standing waves on wires. Lodge admitted that Hertz had provided more striking evidence of electromagnetic waves by measuring their length with an interference experiment that he gratuitously observed was exactly like one used by Lord Rayleigh for an

experiment with sound. Nevertheless, Lodge insisted that he too had discovered the existence of ether waves, albeit by a method different from that of Hertz. If Lodge had listened carefully to FitzGerald's speech, he would have heard that standing waves on wires do not provide evidence of ether waves in space.

The relevant introductory words he gave in his paper are reproduced in the sidebar entitled "Excerpt from Lodge's Bath Paper on Wave Measurements."[76] A number of these statements were either gratuitous or deceptive. Three of the most deceptive statements are highlighted in bold print in the sidebar entitled "Excerpt from Lodge's Bath Paper on Wave Measurements."

Standing Waves on Wires Are Not the Same as Propagating Waves in Space

Lodge stated that he had "proved the existence of ether waves of various lengths," despite FitzGerald's admonition to the contrary: "Specific inductive capacity, the action of intervening matter, *the delay in telegraphing, the time propagation of electro-magnetic actions by means of conducting material* [emphasis added]—these were known, but he [Maxwell] knew that they could be explained by means of action at a distance, and had been so explained."[77] The ether waves to which both Lodge and FitzGerald referred were clearly the ether waves in free space, not *the time propagation of electro-magnetic actions by means of conducting material*, such as the delays on telegraph lines. Lodge attempted to obfuscate this issue in many ways, but none more misleading than the following two statements he made later in life:

> "I don't think anyone quite realized—at any rate, not clearly—that waves which I had directed along wires followed exactly the same laws as the waves which Hertz detected in space. Their theory is given in…the Philosophical Magazine for August 1888. The waves really travel through the ether in either case, and both sets of experiments verify Maxwell's theory.[78]
>
> "He [Hertz] found the evidence of the waves on the same principle as I found them, by the nodes and loops which were produced by the interference of the direct and reflected pulses; but he found them in space, instead of long wires; though, after all, the law of propagation is the same, and to a mathematician like Oliver Heaviside the two sets of experiments seemed to amount to the same thing."[79]

Lodge's assertion that the law of propagation for waves on transmission lines is the same as ether waves in free space was not true. The telegrapher's equation that Lodge used to describe standing waves on wires in his August 1888 publication in *Philosophical Magazine* was derived by Heaviside using a form of the telegrapher's equation that was first developed by William Thomson (later Lord Kelvin) in 1855 using Kirchhoff's circuit law. This model was later revised by Heaviside in 1876,[80] who added the important terms for inductance L and leakage conductance G (see Fig. 19).[81]

Excerpts from Lodge's Bath Paper on Wave Measurements

I hit on an arrangement which, without any thought or scheming at all, gave me evidence of the very waves I had been thinking so much about, and enabled me to measure their lengths, though not in a previously planned-out way. I described these experiments quite hastily and briefly in the midst of other matter, in a lecture to the Society of Arts last March on lightning conductors, as "the experiment of the recoil kick."

I continued the experiments after the lecture, and proved the existence of ether waves of various lengths, the shortest wave that I obtained distinct evidence of being three yards. I intended to describe those experiments at this meeting with a reference to the Southport suggestion of Prof. FitzGerald quite unknowing at the time that we should have the pleasure of seeing him in the chair. However, when going away from Liverpool on a holiday I read in the train the July number of Wiedemann's *Annalen*, and there found that Dr. Hertz had obtained much better and more striking evidence of these electro-magnetic waves, and had measured their length by an interference experiment exactly like one of those used by Lord Rayleigh for sound.

I hasten to acknowledge the superiority of Hertz's method of demonstration to my own; and so far as evidence of the waves is concerned **a description of my experiments is now superfluous**. **Nevertheless, the mode of propagation of the pulses and their mode of reflection is different in my experiments from what they are in those of Hertz,** and although mine is not so good a method, yet it may have some interest as confirming the view taught us by Poynting and others concerning the mode of propagation of energy through the ether, and the theory of Kirchhoff and Heaviside concerning the rate of transmission of signals by a telegraph wire.

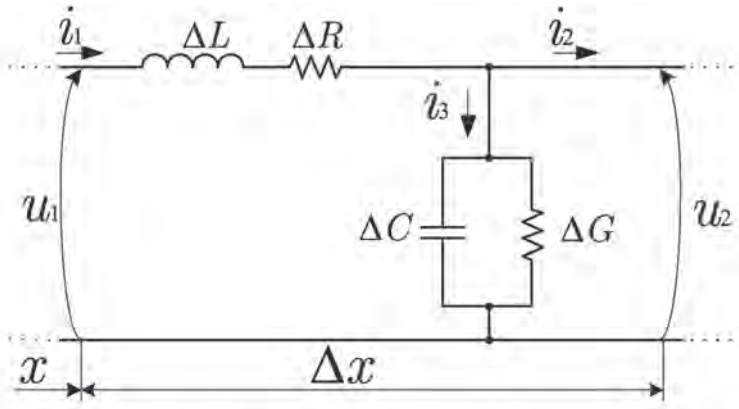

Fig. 1 Elementary circuit of classical transmission line model

Fig. 19. Heaviside improved the telegrapher's equation, which was developed by William Thomson (later Lord Kelvin) in 1855 using Kirchhoff's circuit law, by adding elements for inductance ΔL and leakage conductance ΔG. (Cveticanin, et. al., *Nonlinear Dyn. Vol.* 88, pp. 1453–1472)

The equation was revised into its final form by Heaviside circa 1885. Heaviside's model predicted that electromagnetic waves can be reflected on transmission lines, and wave patterns such as standing waves can form along the line, but it could not predict the existence of propagating electromagnetic radiation in free space. It is true that the same equation can be derived from Maxwell's equations with certain assumptions, but that does not mean the telegrapher's equation can predict or describe propagating electromagnetic waves in free space of the type Maxwell predicted with his equations. To say that the discovery of waves on wires verifies Maxwell's equation for waves in free space is the same as saying verifying Kirchhoff's circuit law also verifies Maxwell's equations for waves in free space.

Indeed, the laws of propagation for waves on wires do not follow the same as the laws of propagation for electromagnetic radiation in free space. For example, propagating waves in free space are planar waves in which:

- electric and magnetic fields are normal to each other and to the direction of propagation,
- electric and magnetic fields are in phase,
- electric and magnetic fields propagate energy,
- the ratio of the electric field E to the magnetic field H is equal to the free space impedance of 377 ohms, and
- the amplitudes of the electric and magnetic fields fall off as 1/r in the direction of propagation.

On the other hand, the electric and magnetic fields for standing waves on a low-loss, straight and parallel two-wire transmission line with a length much greater than the separation distance:

- are not planar,
- are 180 degrees out of phase and do not propagate energy,
- do not have a constant ratio,
- do not fall off as 1/r in any direction, and
- do not radiate significant electromagnetic radiation to the far field.

While the telegrapher's equation, per se, does not predict the velocity of waves on wires, measurements of the wavelengths of standing waves on wires combined with the knowledge of the source frequency producing the standing waves can be used to calculate the speed of waves on wires. In November 1887, Hertz measured the standing wavelength λ on a wire that was excited by his dipole oscillator with a frequency *f,* and he was the first to calculate the speed of waves on a wire by using the equation $v = \lambda f$. Unfortunately, he miscalculated the frequency of his source by a factor of 1.41 and predicted that the speed of waves on a wire was 200 km/sec. Nevertheless, the speed of waves he predicted on wires was on the same order of magnitude as the speed of light, and based on his results he concluded, quite correctly, that the action-at-a-distance theory was incorrect.

Lodge's Claim to Observe Waves as Short as Three Yards was Deceptive

Lodge claimed that he "proved the existence of waves of various lengths, the shortest wave that I obtained distinct evidence of being three yards." Recall that Lodge had reported in a footnote to his paper published on June 22, 1888, the shortest wavelength he had obtained as of that date was 30 meters: "Since the delivery of the lecture, a great number of quantitative observations on these lines have been made. Evidence of electromagnetic waves 30 yards long has been obtained." In fact, in 1891 he published a description of this experiment, which he said was performed in May 1888, confirming that he observed a resonant wavelength of approximately 30 meters in a recoil kick experiment.[82]

Lodge did not report any quantitative results in his August paper in the *Philosophical Magazine*, nor did he present any data in his British Association paper, so how and when did he "obtain distinct evidence" of the shortest wavelength being 3 yards (~ 3 meters) with his recoil kick experiment? The deceit inherent in Lodge's statement became evident when he made this statement in yet another paper he published immediately after the Bath meeting:

> "A gallon Leyden jar, discharging through a stout wire suspended round ordinary sized room, emits waves between three or four hundred yards in length, its current alternating at the rate of a million per second. A pint Leyden jar, sparking through an ordinary pair of discharge tongs, gives a current of 15 million alternations per second with ether waves some 20 yards in length [18 meters]. An ordinary *electrostatic charge on a conducting sphere two feet in diameter* [emphasis added], if disturbed in any way, will surge to and fro at the rate of 300 million vibrations a second, emitting waves a yard long [0.9 m]."[83]

In this paper, Lodge did not claim that he had "obtained direct evidence" of the fields radiated from the sphere, nor did he state how he measured waves so short. If Lodge actually performed an experiment to measure the resonant frequency of an isolated sphere, how did he measure or observe the wavelength of an electric field emitted by an isolated sphere? Such a measurement could have been accomplished on an *isolated* sphere at that time only by using a resonant loop detector of the type that Hertz had invented. It is obvious that Lodge simply estimated the resonant frequency of an isolated sphere by assuming the resonant wavelength was approximately equal to its circumference.

Lodge's Deceptive Claim that his Method of Discovery was Different from Hertz

Lodge went on to state "the mode of propagation of the pulses and their mode of reflection is different in my experiments from what they are in those of Hertz." If we are to believe this claim, which appeared first in the postscript he wrote in July 1888 and repeated in the paper he read at the British Association meeting, then we must believe that Lodge had not read Hertz's paper in issue No. 7 of *Annalen*, which had been published four months earlier on May 15, 1888. This paper described Hertz's discovery of standing waves on wires and the method he introduced to determine the speed of light of light on wires by multiplying the measured wavelength by the frequency of the source that produced the standing waves. If Lodge hadn't read Hertz's paper on wires by the middle of September, he might have been one of the few people at the meeting who were not aware of it.

It is almost certain that Lodge was well aware Hertz had made measurements of waves on wires, but remained silent about it because he needed to differentiate his work from that of Hertz. After all, if Lodge had made reference to Hertz's work on wires in his paper at the British Association meeting, there would have been no reason for Lodge to present his paper. To add insult to injury, Lodge claimed that Hertz had discovered the waves by the same principle (interference) as he (Lodge) had found them on wires. In fact, it was just the other way around. Lodge found them on wires by the same principle that Hertz found them, and well before Lodge even began his experiments with his recoil kick experiment on March 1, 1888.

Lodge Failed to Provide Numerical Results

Lodge stated in his August 1888 paper that he intended to present some numerical examples at the meeting, but later he wrote that he neglected to do so. Indeed, the paper he published presented conceptual results only, in particular the one shown in Fig. 20 where he sketched how he believed the magnitude of the response at the end of his wires at point B would vary as a function of the length of the wires L in his *source*, not in his transmission line.[84] By increasing the length of the wires in his source, he lowered its frequency and increased its wavelength. Lodge had originally proposed

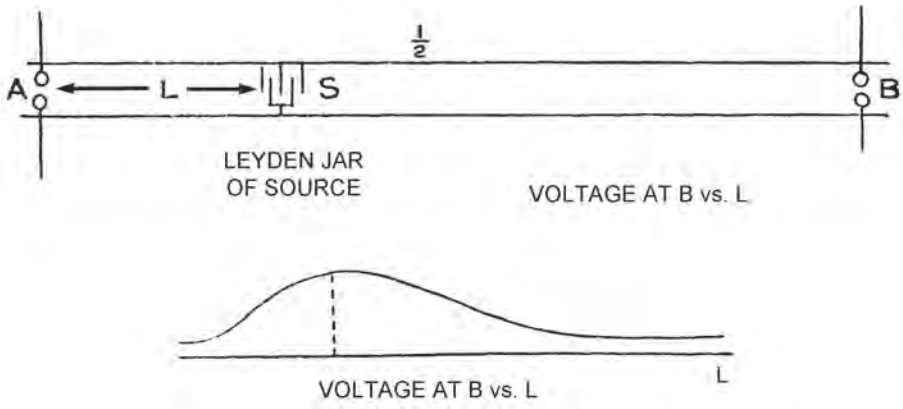

Fig. 20. Lodge's concept for determining the frequency of a source with a spark at A that discharges the Leyden jar (top), and the conceptual voltage for the response at point B at the end of a transmission line produced by the discharge for various lengths of wire L between the Leyden jar and discharge knobs at A, which controlled the frequency of the source (bottom). (*Electrician*, Vol. 21, Sept. 14, 1888, p. 608, modified)

this concept as an approach to determine the frequency of a source, but that would have worked only if he had varied the length of the transmission line.

Lodge's sketch of the conceptual voltage response at point B on the transmission line as a function of length of wire L (connecting the Leyden jar to the sparking knobs A of the source) is shown in the lower portion of the figure. It is clear that he did not actually do this experiment because there are two fundamental problems with the sketch. First, the actual response would have had multiple *sharp* resonances at discrete lengths of the wire L rather than a single broad response covering a range of lengths, as if the resonance occurred over a large and continuous range of frequencies. An example of how sharp a resonance would have been is illustrated by Hertz's measurements shown previously in Fig. 11. As the magnitude of a resonance increases, the bandwidth of the response becomes even narrower. The second problem is the response at B would never have been less than twice the applied voltage because a reflection at the open end of the line would have doubled the response, even in the absence of a resonance.

Lodge Rewrote the History of his Discovery of Ether Waves (June 4, 1891)

At the 1888 meeting of the British Association in Oxford, Lodge had admitted that his method of discovering electromagnetic waves by observing standing waves on wires was "superfluous." Nevertheless, he maintained all the while that he had discovered the electromagnetic radiation predicted by Maxwell at about the same time Hertz did, albeit, not in such an elegant manner. Lodge doubled down on this assertion three years later by writing a paper entitled "Experiments

on the Discharge of Leyden Jars," which was read to the Royal Society on June 4, 1891, and published shortly thereafter in its proceedings.[85] Ostensibly, the intent of this paper was to explain and expand on his earlier experiments with Leyden jars that took place in the context of lightning conductors in early 1888, but in reality it was a thinly-veiled treatise to revise the history of his contributions and reassert that he independently discovered the electromagnetic radiation predicted by Maxwell.

Lodge introduced this paper by stating that he had performed experiments with the discharge of Leyden jars beginning in February 1888, and that only a brief account of these experiments had been presented at his lecture to the Society of Arts on March 17, 1888. He then claimed that some of the experiments not yet documented had "led to some interesting observations concerning electromagnetic waves, and incidentally *measured the velocity of transmission of a pulse along an isolated wire* [emphasis added]." He concluded by saying that "they ought to have been written out for publication long ago," and that he intended to communicate them in this paper "to render the steps intelligible." After presenting a summary of some of his experiments involving the discharges of Leyden jars, Lodge presented a section entitled "Historical Observations," which is an astonishing revisionist history of his work. The focus of this section is a summary of that revisionist history.

Lodge Misrepresents FitzGerald's Advice on How to Find Electromagnetic Waves

Lodge begins his account of how he discovered waves on wires by recalling the advice FitzGerald gave at the Southport meeting of the British Association in 1883 about where to search for the electromagnetic waves predicted by Maxwell:

> "This evidence of the existence of electro-magnetic waves seemed to me of considerable interest, because I had been for some years contemplating the production of radiation by direct electro-magnetic experiments, the difficulty being their detection, i.e., the proof of their existence.
>
> "But two years later, at Southport [1883], FitzGerald pointed out that a discharging Leyden jar must emit radiation, and that though its waves would be yards *or miles long* [emphasis added], yet it might not be hopeless to prove that they were waves *by obtaining interference phenomena* [emphasis added]."[86]

This is not what FitzGerald wrote. The actual advice that FitzGerald gave at Southport about how to find these waves was "by utilizing the alternating currents produced when an accumulator [Leyden jar] is discharged through a small resistance. It would be possible to produce waves of as little as ten metres wave-length, or even less."

FitzGerald gave advice on how to look for the waves as little as ten meters in wavelength—not with the added words "or miles long." Also, FitzGerald said

nothing about looking for the waves *by obtaining interference phenomena*. Lodge revised FitzGerald's advice to make it consistent with how he claimed he found standing waves on wires—namely, with waves 60 meters long using interference phenomena.

Lodge Alters the Description of How he Discovered Standing Waves

Lodge goes on to expand on his description of how he discovered and observed the standing waves:

> "Some of Lord Rayleigh's large-scale interference experiments with sound waves, exhibited to the Royal Institution on January 20, 1888 (*Nature*, Vol. 38, p. 208), re-awakened in me the hope that such experiments were possible, and the desire to try them. And now simply by attaching long wires to a discharging Leyden jar circuit, the waves had become without trouble conspicuous.…"[87]

Lodge was attempting to make it appear that he had thought of using interference measurements to discover electromagnetic waves as early as January 1888. This description directly contradicted Lodge's earlier published version of how he discovered standing waves on wires. In an article appearing in the *Electrician* on November 9, 1888,[88] Lodge claimed he stumbled on the recoil kick experiment during the course of his experiment of the alternative path (see Fig. 21). Referring to this figure, Lodge claimed he was performing a number of

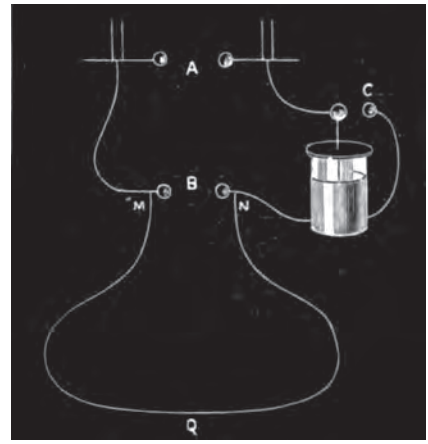

Fig. 21. Lodge claimed he stumbled on the recoil kick experiment during the course of his experiment of the alternative path after he cut the alternative path wire at Q and observed brushes and vigorous disturbances. (Lodge, *Electrician*, Vol. 22, p. 8)

variations of this experiment when he cut the wire at point Q in the middle of the path going around the room (the other path being the gap B). He wrote, "with wire cut in middle and ends separated by a few inches…the brushes and vigorous disturbances subsequently seen at this gap led on to a series of experiments on 'the recoil kick'."[89] Note that he called this experiment the "recoil kick" experiment, not the "interference" experiment or the "resonance" experiment. He also claimed, "I hit on an arrangement which, without any thought or scheming at all, gave me evidence of the very waves…" Lodge actually stumbled on the recoil kick experiment serendipitously, not because he was thinking of Rayleigh's large-scale interference experiments and had a desire to try them.

Lodge Concedes that He May Not Have Observed Half-Wavelength Resonances

Lodge had asserted in 1888 that he had observed 60 meter standing waves on his 95 foot (30 meter) cable, and he provided a convoluted and specious calculation in an attempt to support his claim. In that calculation he stated that the Leyden jar capacity of his two gallon-sized jars was 0.002 microfarads.[90] However, in this paper Lodge repeated the same calculation, only this time he used a capacitance of 0.003 microfarads—a 50% increase over the capacitance of exactly the same two Leyden jars (in series) that he used in his 1888 recoil kick experiment. It turns out that it was not until sometime around November 1888 that Lodge actually calibrated his Leyden jars.[91] Lodge never mentioned the fact that he had not calibrated the capacitors he used in his Mann lectures, and he did not call attention to this change in capacitance in his 1891 paper. Using the new value of capacitance in his recalculation, Lodge concluded that the waves produced by his source were actually longer than 60 meters (see Table 8). Because the wavelength of Lodge's source was proportional to the square root of the capacitance of his Leyden jars, a change in capacitance by a factor of 1.5 would have changed Lodge's estimate of wavelength by a factor of the square root of 1.5, or 1.22.

Table 8. Lodge's earlier calculations compared with a later recalculation using an updated value of Leyden jar capacity (differences in calculations are highlighted by shaded boxes).

Parameters	Lodge's Calculation (June 22, 1888)	Lodge's Recalculation (June 4, 1891)
Capacitance C of two gallon-sized Leyden jars in series	$C = 0.002$ μF	$C = 0.0031$ μF
Wire length, $\ell = 95$ feet (30 m)	$\ell = 30$ m	$\ell = 30$ m
Presumed half-wavelength resonance on wires pair $\lambda_W = 2\ell$	$\lambda_W = 60$ m	$\lambda_W = 60$ m
Assumed wave speed $v = c$	$c = 3 \times 10^8$ m/s	$c = 3 \times 10^8$ m/s
Period of waves on wires	$T_W = \lambda_W/c = 0.2$ μs	$T_W = \lambda_W/c = 0.2$ μs
Other Assumptions	$T_S = T_W$	$T_S = T_W$
Calculated source inductance L	$L = (T_S/2\pi)^2/C^*$ $= 0.5$ μH $T_S = T_W = 0.2$ μs $C = 0.002$ μF	$L = (T_S/2\pi)^2/C^*$ $= 0.32$ μH $T_S = T_W = 0.2$ μs $C = 0.0031$ μF
Comments on the size of Lodge's computed inductance L	"Reasonable enough"	"Too small. Waves are longer than 60 m."
Wire wave period T_W ($v = c$)	$T_W = \lambda/c = 0.2$ μs	$T_W = \lambda/c = 0.2$ μs
Source period T_S	$T_S = T_W = 0.2$ μs	$T_S = T_W = 0.2$ μs
Source wavelength λ_S	$\lambda_S = cT_S = 60$ m	$\lambda_S = cT_S = 60$ m
Wire wavelength λ_W	$\lambda_W = cT_W = 60$ m	$\lambda_W = cT_W = 60$ m
Source frequency $f_S = 1/T_S$	$f_S = 5$ MHz	$f_S = 5$ MHz

*Solving for L using $T_S = 2\pi\sqrt{LC}$

Lodge's 1891 admission that the "waves are longer than 60 meters" is much more important than one might think. This is not just a case where the waves might be, say 70 meters, instead of 60 meters. If the primary harmonic on his wires was actually a half-wavelength resonance, as he believed in 1888, his source with a wavelength greater than 60 meters could not have produced any standing waves on his 30 meter wires. Lodge finally recognized this fact in his June 1891 paper, where in a footnote he allowed that the waves from his source *may* have been a quarter-wavelength resonance: "Or else that each wire behaves like an organ-pipe open at one end only, and so it is a quarter of a wave long. — June, 1891."[92]

The second reason Lodge's admission is so important is that it means Lodge did not directly measure the nodes and loops of his waves on wires in 1888, as he claimed throughout his life. If he had actually measured the nodes and loops directly in 1888, a subsequent change in the value of the capacity of the jars would not have affected the result of a *direct measurement* of the waves. Lodge's admission is actually prima facie evidence that he did not actually observe or measure standing waves on his wires in 1888.

The changes in Lodge's new calculation are highlighted by the shaded boxes of the table. Note that the change in the value of capacitance did not change his computed value of the source period, source frequency, or speed of the waves on the wires (see the last three lines in the table). It only changed the computed value of the inductance required for his source to produce a 60 meter standing wave, and Lodge concluded that the inductance required to produce a 60 meter wave was too small for his Voss machine and Leyden jars. The fact that a change in the value of his capacitance did not change the calculated period or frequency of his source represents a fundamental shortcoming in Lodge's convoluted calculation methodology.

Lodge Asserted that he Measured Visible Standing Waves

Lodge asserted in his 1891 paper that he was able to see the standing waves from the glow on the wires and measure the lengths of the standing waves directly, just as Melde did in his string experiment (see Fig. 22):

> "And now, simply by attaching long wires to a discharging Leyden jar circuit, the waves had become without trouble conspicuous. One had only to lengthen the wires enough, and to look at them in the dark, to see by the brushes the nodes caused by the interference of the direct and reflected pulses surging to and fro in the wires; to see in fact the waves themselves, and to measure their length in a manner precisely analogous to the well-known experiment of Melde.
>
> "The fact that electric waves could be thus detected and measured, I stated at the Society of Arts, on March 17, 1888, and published more precisely in the 'Phil. Mag.' for August, 1888."[93]

This is an incredible distortion of fact, which was inconsistent with all of

Lodge's previous publications. In the paper he wrote to document the speech he gave at the British Association meeting on September 7, 1888, which was published on September 14, 1888, Lodge admitted that he had not yet attempted such an experiment: "With very long wires arranged out of doors on a dark night I hope to get evidence of modes by the periodic glow."[94]

Also, in Lodge's paper published on June 22, 1888, Lodge claimed he observed a half-wavelength resonance in his recoil kick experiment—in accordance with the Melde experiment. A half-wavelength resonance on an open-ended transmission line manifests itself with a local maxima at both the source end and the open end, and a null or node in between the two maxima (see previous Fig. 7). However Lodge clearly stated that he saw a glow only at the far end, and said nothing about any darkness at the midpoint:

> "Making the experiment in the dark, a very interesting effect is seen; the *further end of each wire glows with a vivid brush light* [emphasis added]; showing the exceedingly high potential to which they are raised by the recoil… With the two gallon jars the wires glow over fully three-fifths of their entire length. With jars of much larger or much smaller capacity the length of glow is conspicuously less."[95]

Lodge repeated this claim in his talk at the meeting of the British association in Bath in 1888:

> "Now take the wires of finite length. At the free ends we shall have reflexion, a sort of recoil or kick evidenced by a brush discharge or spitting off from the ends of the wire, and in the dark the far ends of the wires glow."[96]

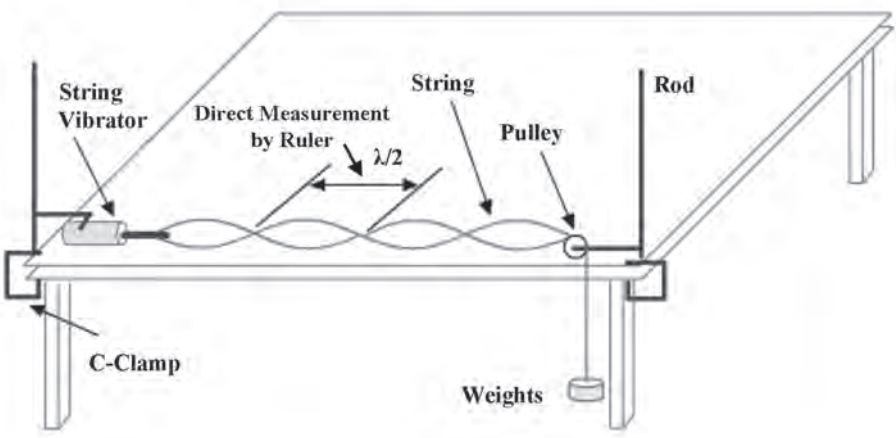

Fig. 22. Lodge claimed he measured the length of standing waves on wires "in a manner precisely analogous to the well-known experiment of Melde," who measured the half wavelength on a string with a ruler. (http://www.pstcc.edu/nbs/WebPhysics/Expm%2002.htm, modified)

Even in this paper where Lodge made his statement about observing and measuring the waves optically, he also stated that the glow occurred at the end of the wires:

> "The brush or sparking out from the wires, which I call the recoil kick, is most marked at certain places on those wires; and usually at the distant ends. Occasionally these brushes extended over a considerable length of wire, giving them a peculiar luminous appearance at each discharge."[97]

Two short weeks after these words about directly measuring waves in the manner of Melde were published, Lodge attempted to demonstrate a measurement of the wavelength of standing waves with optical signatures in a lecture to the Physical Society, but failed to do so. This fact was reported in June 19, 1891, by a witness to Lodge's presentation to the Physical Society:

> "By using long wires he [Lodge] had observed a glow on portions of them with the intermediate parts dark: this corresponded with the first harmonic, and, by measuring the distance between two nodes, he had determined the wavelength of the oscillations. The length so found did not agree very closely with the calculated length…"[98]

In fact, the first harmonic of a resonance on a pair of wires with an open-circuit at the end—whether it be either a quarter-wavelength or half-wavelength resonance—has only a single node. Lodge never did publish a paper demonstrating his ability to determine wavelengths with an optical signature.

Lodge's Deceitful Claim of Demonstrating Electric Waves in Air on March 8, 1889

Lodge claimed that he unexpectedly demonstrated the existence of electromagnetic waves at a lecture entitled "The Discharge of Leyden Jars" at the Royal Institution on March 8, 1889:

> "In the comparative freedom from students of Karlsruhe, he [Hertz] struck on the influence between one circuit and another across space, and so made the astonishing discovery that the radiation in air was intense enough to cause sparks in conductors upon which it fell. This same discovery would have been made by the audience at the Royal Institution on the evening of March 8, 1889, if it had not been made before; for, during a lecture on Leyden jars [by Lodge], every time one was discharged through a considerable length of wire, the heavily gilt wall paper sparkled brightly, by reason of the incident radiation.
>
> "The achievement of Hertz is well known, and it is only the customary interest attaching to circumstances connected with what will probably be regarded as an epoch in electrical science that constitutes my excuse for making the above statement."[99]

This demonstration is not particularly relevant in an historic sense because it was presented well after Hertz had

demonstrated the existence of electromagnetic waves in air almost a year before. However, it is surprising that Lodge would claim he observed electromagnetic waves in free space using a considerable length of wire around a lecture room caused by the discharge of a Leyden jar—something he had done before with his recoil kick experiments on a number of occasions without claiming he had observed electromagnetic waves. So what was different on the occasion with his Leyden jar discharge demonstration to the Royal Institution on March 8, 1889?

Unfortunately, Lodge gave no details in terms of the number and length of wires, the location of the wires relative to the wall, or the size of the Leyden jar. However, Lodge consistently stated that, "A gallon Leyden jar, discharging through a stout wire suspended round ordinary sized room, emits waves between three or four hundred yards in length [i.e., 274–365 meters], its current alternating at the rate of a million per second."[100]

The currents flowing in a single wire that produce radiation in the far field also produce significant non-radiating electrostatic fields in the vicinity of the wire. It is not until a distance greater than about one-sixth of a wavelength from the wire is reached that the radiated electromagnetic fields exceed the electrostatic fields. Thus, for a wire radiating electromagnetic waves at, say 300 meters, the electromagnetic fields do not become significant compared to the electrostatic fields until a distance of one-sixth of 300 meters is reached, which is 50 meters. It is clear that a wire in Lodge's lecture room would have been much closer to the wall than 50 meters. For a single wire, it would have been the *electrostatic currents* that returned to the other side of the Leyden jar through the metallic wallpaper that caused the glow. In short, Lodge could not have demonstrated the existence of electromagnetic fields in his lecture room with waves in the range of 274–365 meters.

Another way to look at this claim is to recall that Hertz was barely able to demonstrate the existence of electromagnetic waves in free space in his rather large laboratory using waves as short as 6 to 8 meters long. So how could Lodge have demonstrated the existence of electromagnetic waves in free space in a lecture room much smaller than the 300 meter wavelength that Lodge claimed was radiated by his wire?

Why is this vignette particularly relevant? I believe the reason Lodge claimed he radiated electromagnetic waves in his lecture can be found in the last sentence in the above citation where he stated quite candidly:

> "It is only the customary interest attaching to circumstances connected with what will probably be regarded as an epoch in electrical science that constitutes my excuse for making the above statement."

This statement supports the thesis of the paper that Lodge made his deceptive claims about his recoil kick experiment so that he could attach his name to the discovery of electromagnetic waves. He succeeded, but not for the right reason.

Lodge Falsely Claimed He Measured the Velocity of Waves on Wires

Lodge completed the reconstruction of his historical observations by restating the claim that he made in the introduction to this 1891 paper, namely that he had measured the velocity of a pulse along a wire:

> "One point, about which there has been some controversy, my experiments do make clear, viz., that the velocity of a pulse along an isolated thin copper wire is practically identical with the speed of light; in accordance with the theory based on Maxwell, and previously mentioned. Hertz at one time stated, as the result of some of his experiments, that there was considerable discrepancy between the speed of waves along wires and of waves in free space; and, though my own experiments were (to me at least) conclusive in the opposite direction, yet as they had not been published in detail, they could not be properly taken into account."[101]

There is not a shred of evidence that Lodge ever determined the velocity of waves on wires using data from his recoil kick experiments. He consistently used his measurements from the recoil kick experiments to calculate the inductance of his source by assuming *a priori* that the speed of waves on wires was equal to the speed of light. How could he possibly state that his experiments conclusively showed the speed of waves on wires was equal to the speed of light when his calculations always assumed *a priori* that the speed was the speed of light?

Note that Lodge admitted his results "had not been published in detail" and "could not be properly taken into account." The truth is that Lodge never published a calculation of the speed of waves on wires. If he did, which value of capacitance did he use to determine the wavelength of his two gallon-sized Leyden jars for his source—the 0.002 microfarad value he claimed in his 1888 papers, or the 0.003 microfarad value he claimed for the same jars in this 1891 paper after recalibration? The difference in the two capacitances (50%) translates into a significant difference in the speed of waves on the wires when the calculation is performed correctly (proportional to $\sqrt{(1.5)}$ or 22%). After all, the Maxwellians expected the speed of waves on wire in air to be virtually equal to the speed of light. A 22% change in the result may not seem to be significant, but a 22% deviation from the speed of light would have raised eyebrows in the scientific community—just as Hertz's error in the calculation of the capacitance of his source resulted in a 41% deviation from the speed of light—which really raised eyebrows.

Lodge actually attempted to cast aspersions on Hertz's measurement technique with this untrue statement:

> "Hertz had also worked on wires to some extent either then or later, and found an apparent discrepancy between the velocity along wire and the velocity in air.… Subsequent experience has led Dr. Hertz to accept this conclusion,

> and to suppose that reflection from walls, or some other disturbing cause, vitiated the quantitative accuracy of those particular experiments of his."[102]

The error in Hertz's work was not in the measurement technique, but in his calculation of the capacitance of his oscillator. Hertz actually wrote Lodge in a letter dated July 21, 1889, well before Lodge published his book in 1892, and informed him of that fact:

> "The capacity of the terminating spheres in the product capacity x coefficient of self induction is to be put down as half the radius, not the radius itself. So all my calculated vibration times are too great in the proportion of √2:1. I beg to state however that this does not affect my calculations on radiations as there is always taken account of observed wave lengths, not of calculated ones."[103]

In the last sentence, Hertz attempted to say that the determination of the wavelengths on the wires was not affected by the error in the calculation of the frequency of his source because the measurement of the wavelengths did not depend on the error in his calculation of capacitance. Lodge was well aware that Hertz did not believe there was "a disturbing cause" that would have "vitiated the quantitative accuracy of those particular experiments." Lodge's comment was both disingenuous and hypocritical because Lodge had been informed of the situation in writing and because he had made an error in the determination of his Leyden jar capacitance in his recoil kick experiment by a factor of √(1.5):1, or 22%—versus Hertz's error of 41% in his calculation. Lodge's error would have also caused a significant error in the speed of the waves, had he published his calculations based on the experiments he published in June 1888 versus his publication in June 1891.

Summary and Conclusions

Summary

Eight major findings from this study are summarized below. These findings lead to the conclusion that Lodge was deceptive about many of his claims, and in particular his claim that he discovered or observed standing waves in his recoil kick experiments. With the possible exception of the final entry, these findings have not been chronicled by previous historians.

1. Lodge did not discover standing waves or resonances on wires independently of Hertz. Lodge's first publication that documented the results of his lightning experiments, and in particular his recoil kick experiment, was dated June 22, 1888. In this document Lodge wrote a footnote acknowledging that he had read that "*Dr. Hertz has made experiments on electric oscillations very like those of mine on 'the surging circuit'* (Wied. Ann., 1887)." The reference to *Annalen der Physik* in Lodge's footnote was to Hertz's paper on the discovery of waves on wires that was published on May 15, 1887. By reading this paper, Lodge would have learned that Hertz discovered standing waves on loops of wires excited by his dipole oscillator source when the resonant wavelength of

the wire circuits matched the resonant frequency of his oscillator, that Hertz had generated very short wavelengths on the order of eight meters, and he observed nodes of standing waves on what would become his resonant loop detector. Thus, anything Lodge wrote in his papers on this subject, beginning with his publication on June 22, 1888, is tainted by what he read beforehand about Hertz's work. Lodge did not discover waves on wires independently of Hertz.

2. Lodge was deceptive when he claimed he performed his experiments with standing waves on wires simultaneously with the experiments of Hertz. Hertz began his experiments with standing waves on wires in late 1886 and completed them in November 1887 by mapping out the nodes and loops produced on a long wire by resonances with his dipole oscillator, the results of which were published on February 9, 1888, before Lodge performed his first recoil kick experiments beginning on March 1, 1888. To claim that Lodge and Hertz performed their experiments with waves on wires simultaneously misrepresents the fact Lodge did not perform experiments with waves on wires during the entire time that Hertz did, from late 1886 to November 1887, the month that Hertz completed his experiments with waves on wires and began his search for waves in air.

Hertz began his experiments with waves in air in November 1887 and reported his discovery of waves in air on March 13, 1888, while Lodge began his recoil kick experiments with waves on wires on March 1, 1888, and first disclosed them in his lecture on March 17, 1888. To say that the two experimented with waves at the same time ignores the fact that the two experiments were totally different, and that the overlap in time was only two weeks of the many months after March 1888 that Lodge continued with his experiments.

3. Lodge's recoil kick experiment configuration did not record standing waves on wires. Because the wires in Lodge's recoil kick experiment were attached directly to the Leyden jars, the wires were charged at the same time the Leyden jars were charged, typically to voltages of 10 to 30 kV before discharge. Because the detector knob gaps could never be set to gaps less than the primary discharge gaps, the voltages that Lodge measured across his wires could never be less than the charging voltage. Thus, only voltages greater or equal to the charging voltage could be observed and measured by the B discharge knobs between the two wires. This is evident from the data, in which all ratios of detector gap voltages to primary discharge voltage were greater than unity. As a result, Lodge was never able to observe nodes, or nulls, with his recoil kick experiment, and all his claims that he observed and measured loops and nodes with the data from his recoil kick configuration were false.

4. Lodge's erroneous assumption that the primary resonance on his open-circuited transmission line was a half wavelength led him to an erroneous conclusion that he had observed a resonance on his line. Lodge claimed that the primary

resonance on his open-circuited transmission line was a half wavelength, when in fact it was a quarter wavelength. Because he believed that the largest response occurred for the primary harmonic, and because he was not able to measure it directly, he assumed that the largest response he observed corresponded to a half-wavelength resonance. He later realized that his data was not consistent with a half-wavelength response and in 1891, he allowed that it might have been a quarter-wavelength resonance that he had observed in 1888.

5. Lodge did not observe or measure standing waves on wires by the glow on the wires. When Lodge first documented his recoil kick experiment on June 22, 1888, he disclosed that "the further end of each wire glows with a vivid brush light," which was due to the doubling of the voltage at the end of the line. And then, on June 1, 1891, for the first time ever, he expanded his claim by saying that he was able to measure the nodes and loops in 1888 by the optical signatures consisting of brushes, or glows on the wires: "By attaching long wires to a discharging Leyden jar circuit, the waves had become without trouble conspicuous. One had only to lengthen the wires enough, and to look at them in the dark, to see by the brushes and the nodes caused by the interference of the direct and reflected pulses surging to and fro in the wires; to see in fact the waves themselves, and to measure their length in a manner precisely analogous to the well-known experiment of Melde." In fact, observers of his later attempted experiments in 1891 documented the fact that he was unable to identify the loops and nodes by the glow from the antinodes of his wires.

6. There is no evidence embedded in the data Lodge published in 1888 that would indicate he observed standing waves. There are three reasons to believe that Lodge did not observe standing waves with his recoil kick experiment. First, the maximum response that Lodge reported at the open end of his wires was twice the voltage at the point of discharge of the primary circuit, which is consistent with the reflection of a wave from an open circuit without a resonance. Second, his measurements at the three points on his wires (source end, middle, and far end) were inconsistent with the standing wave pattern he claimed he had observed—to wit, a half-wavelength resonance. Specifically, his data does not show a null at the mid point. Third, none of his data shows a voltage on the line less than the applied voltage, which means he never observed a node, something that appears in all standing wave harmonics.

7. Lodge made a unsupported claim in April 1888 that he "hit on an arrangement [recoil kick experiment] which, without any thought or scheming at all, gave me evidence of the very waves I had been thinking so much about, and enabled me to measure their lengths." The previous four statements that standing waves were not obvious in the data from the recoil kick experiment make it clear that Lodge did not observe standing waves in his data *without any thought or scheming.* Assuming the previous four assertions

are accurate, this statement must be false. Given that Lodge learned about standing waves on wires excited by resonance with an excitation source when he read Hertz's paper, it is much more logical to presume that Lodge learned of standing waves and resonances from Hertz and attempted to find the resonances in the data that he took before he read Hertz's paper.

8. The standing waves on wires that Lodge claimed he discovered in 1888 are not the same as the propagating electromagnetic waves predicted by Maxwell, which was the fundamental prediction that Maxwellians were seeking to verify in the 1880s. Lodge made the erroneous claim that the standing waves on wires provided proof for the existence of ether waves (propagating electromagnetic radiation in free space) that Maxwell predicted, and most historians chronicling Lodge's discovery of waves have not objected to his claim. However, George FitzGerald explicitly stated: "The action of intervening matter, the delay in telegraphing, the time propagation of electro-magnetic actions by means of conducting material—these were known, but he knew that they could be explained by means of action at a distance, and had been so explained. Waves in a conductor do not necessarily postulate action through a medium such as ether." There is no doubt that waves on wires are not the same as propagating electromagnetic waves in free space. And even if they were, then Hertz discovered them first in November 1887 and disclosed his findings on February 9, 1888—well before Lodge disclosed his findings on June 22, 1888.

Conclusions

The above findings support the contention that Lodge reinterpreted his "recoil kick" experiment to make it appear that he independently discovered electromagnetic waves on wires in an experiment that he disclosed to the Society of Arts in a demonstration lecture on the subject of lightning conductors on March 17, 1888. Lodge's story that he "hit on an arrangement which, without any thought or scheming at all, gave him evidence of the very waves he had been thinking so much about," has been disproved. The findings are consistent with the following story of Lodge's involvement with the discovery of electromagnetic waves.

Lodge came across the recoil kick experiment independently of Hertz on the dates of March 1–2, 1888, when he observed voltages at the open end of his two-wire transmission line that were double the input voltage on the line immediately after the spark-gap of his Leyden jar source discharged. The doubling of the voltage at the open end of his transmission line was predicted by the telegrapher's equation, and was no mystery at the time. Lodge named his experiment after the reflection at the end of the wire: "the long spark at the far end of the wires is due to the recoil impulse or kick at the reflexion of the wave."

In the paper describing his experiments that was published on June 22, 1888, Lodge admitted that he had read Hertz's paper published on May 15, 1887, in which Hertz described how he had

discovered, observed, and measured standing waves on wires produced by resonances with his dipole oscillator source radiating short wavelengths of approximately 8 meters. Hertz's experiments were very similar to Lodge's recoil kick experiment, and Lodge reviewed the data from his recoil kick experiment after reading Hertz's paper but before he submitted the paper for publication, to look for evidence of standing waves on wires. Contrary to Lodge's later claims, there was no obvious evidence of standing waves on wires in his data, and Lodge did not actually claim that he had observed standing waves in his publication dated June 22, 1888. Based on a convoluted calculation, Lodge "supposed the wave length of their discharge [Leyden jars] through the A knobs to be something like 190 or 200 feet (twice the length of the leads)."

Within two weeks of the publication of his first paper, Lodge submitted a second paper dated July 7, 1888, in which he summarized the theory of standing waves as derived by Heaviside using the telegrapher's equation. Lodge concluded from his analysis that the primary harmonic for his recoil kick configuration was a half-wavelength resonance, when in fact the primary resonance for a transmission line with an open circuit at the far end is a quarter wavelength. This incorrect conclusion, coupled with a second incorrect assumption that only the largest response at the end of the wires was needed to identify and determine the resonant wavelength, assured that Lodge would never actually observe or measure a resonance with his recoil kick experiment.

On July 24, 1888, while vacationing in the Tyrol of Italy, Lodge added a postscript to the paper he had already submitted on July 7, 1888, in which he claimed, "Since writing the above I have seen in the current July number of Wiedemann's *Annalen* an article by Dr. Hertz, wherein he establishes the existence and measures the length of æther waves excited by coil discharges; converting them into stationary waves, not by reflection of pulses transmitted along a wire and reflected at its free end, as I have done, but by reflection of waves in free space at the surface of a conducting wall." Lodge made the claim that he, not Hertz had discovered waves on wires. He maintained that fiction throughout his life, despite the fact it was well known that Hertz discovered waves on wires long before Lodge. And now it is known that Lodge also was aware of that by reading Hertz's 1887 paper before he (Lodge) documented his first paper on the recoil experiment—and also well before he wrote the postscript dated July 24, 1888.

Beginning in 1891, Lodge began to make many bolder and more deceptive claims, such as claiming that he directly observed and measured the loops and nodes of a half-wavelength resonance both in his measurements and in the glow of brush discharges from the far end of the cable. He claimed that he calculated the speed of waves on wires and determined that it was close to the speed of light, but he never said how close, and he also admitted that he never published the results. Lodge's most outrageous claim was that Hertz "reflected the waves into stationary waves and detected the nodes and loops

so formed, but he used no wires to guide them." Hertz had discovered waves on wires long before Lodge claimed he had discovered waves on wires. The truth is that Lodge did not discover the propagating electromagnetic waves predicted by Maxwell, and the standing waves on the wires of his recoil kick experiment, which he claimed he had discovered, had already been discovered and documented by Hertz well before Lodge.

There can be no doubt that Lodge was successful in convincing many historians that he had discovered ether waves almost simultaneously and independently of Hertz. Unfortunately, many historians have taken Lodge at his word and have not closely examined his claims or his experiments.

Endnotes

The following abbreviations have been used for references to Lodge's journal publications that are cited multiple times in the text. The publication dates are repeated to remind the reader of the time line involved.

Lodge, JSA, 1888: Oliver Lodge, "Protection of Buildings from Lightning – Lecture II," *J. Soc. of Arts*, Vol. 36, June 22, 1888.

Lodge, PM, 1888: Oliver Lodge, "On the Theory of Lightning-Conductors," *Philosophical Mag.*, London, Edinburgh, Dublin, Vol. 26, Aug. 1888.

Lodge, PRS, 1891: Oliver Lodge, "Experiments on the Discharge of Leyden Jars," *Proc. Royal Society*, Vol. 50, June 4, 1891.

1. Oliver Lodge
   —*Talks About Wireless* (Cassell and Co., London, 1925).
   —*Talks About Radio* (George H. Doran Co., New York, 1925).
   —*Advancing Science* (Ernest Ben Ltd., London, 1931).
   —*Past Years, An Autobiography by Sir Oliver Lodge* (Charles Scribner's Sons, New York, 1932).
2. Eric P. Wenaas, "Oliver Lodge's Fanciful History of the Coherer Principle," *AWA Review*, Vol. 28, 2015, pp. 163–220.
3. Charles Süsskind, "The Early History of Electronics, III. Prehistory of Radiotelegraphy," *IEEE Spectrum*, April 1969, p. 72.
4. S. Hong, *Wireless, From Marconi's Black-Box to the Audion*, (MIT Press, Cambridge, MA, 2001).
5. E. P. Wenaas, "Researching the Real Inventor of Radio Telegraphy," *AWA Journal*, Autumn 2013, Vol. 54, pp. 48–53, 60.
6. *Report from the Select Committee on Radio Convention*, Wyman & Sons, Vol. 8, July 8, 1907, p. 157.
7. Oliver Lodge, "Hertzian Waves," *Electrical Engineer* (London), Vol. 14, Aug. 24, 1894, pp. 212–3.
8. Hugh Aitken, *Syntony and Spark, The Origins of Radio*, (John Wiley and Sons, New York, 1976) Chapter 4.
9. James P. Rybak, "Oliver Lodge: Almost the Father of Radio," *The OTB* (now *AWA Journal*), Vol. 43, No. 4, Nov. 2002, p. 27.
10. James Mussell and Graeme Gooday, *Recovering the Life and Work of Oliver Lodge*, (Univ. Pittsburgh Press, Pittsburgh, 2020) p. 47. Peter Rowlands made this claim in his essay appearing as Chapter 2 of this book. Since 1987 Peter Rowlands has been a Research Fellow at the University of Liverpool, the university where Lodge was Professor of Experimental Physics during the time he performed experiments on electricity and magnetism.
11. James Clerk Maxwell, "A *Treatise on Electricity and Magnetism*," Vol. 1 (Clarendon Press, London, 1873).
12. See for example, Bruce J. Hunt, *The Maxwellians* (Cornell University Press, Ithaca and London, 1991).
13. Ole Rømer is believed to be the first to calculate the speed of light in a vacuum using experimental data recorded between 1668 and 1674

on the time differences between eclipses of the Jupiter moon, Io, which depended on whether the Earth was moving away from Jupiter verses when the Earth was approaching Jupiter. For a simple explanation of the calculation, see for example: https://demonstrations.wolfram.com/RomersMeasurementOfTheSpeedOfLight/.

14. Olivier Darrigol, "Poincaré's Light," Seminairé Poincaré XVI (2012), pp. 1–43. See http://www.bourbaphy.fr/darrigolpoin.pdf. This paper presents a good description of the various theories of light and electromagnetic radiation through the eyes of the prominent French mathematician and theoretical physicist, Henri Poincaré, in the years shortly before to shortly after Hertz's experiments.
15. Peter and Neal Graneau, "Newtonian Electrodynamics," (World Scientific Publishing Co., London, 1996) Chapter 1.
16. George FitzGerald, "On a Method of Producing Electromagnetic Disturbances of Comparatively Short Wave-lengths," *Report of the 53th Meeting of the British Association for the Advancement of Science held at Southport in September 1883*, (John Murray, London, 1884) p. 45.
17. Oliver Lodge, *Past Years*, p. 225. This sentence cited in Lodge's autobiography originally appeared in: FitzGerald, *Report of the Fifty-Third Meeting,* p. 405.
18. Lodge, *PRS*, June 4, 1891, p. 2. In 1891, Lodge claimed: "The following experiments among others were made in the course of 1888 beginning in February of that year." The earliest experiment listed was the experiment of the "alternative path," which Lodge claimed began in February 1888. This led to the experiment of the "recoil kick," which Lodge claimed began on March 1, 1888.
19. Oliver Lodge, "Protection of Buildings from Lightning—Lecture I," *J. Soc. Arts*, Vol. 36, Mar. 10, 1888, pp. 867–74.
20. Lodge, *JSA*, 1888, pp. 880–893.
21. Ibid., p. 880.
22. "Discussion," *JIEE*, Vol. 18, May 16, 1889, p. 559; Lodge quote: "I have chosen the frequency of a million a second, because I have shown reason for believing that it is not at all unlikely to apply to the circumstances of lightning."
23. Oliver Lodge, "The Protection of Buildings from Lightning," *Electrical Review*, (New York) Vol. 12, Apr. 14, 1888, p. 6.
24. Lodge, *Modern Views of Electricity*, (Macmillan & Co., London, 1907) pp. 235–36. The English used the Carlsrhue spelling of Karlsruhe with a "C."
25. "Rumford Medal, Professor Oliver J. Lodge, F.R.S." *Year-Book of the Royal Society,* (Harrison & Sons, London, 1899) pp. 154–156.
26. Lodge, *JSA*, June 22, 1888, p. 893.
27. Wilhelm Von Bezold, "Researches on the Electrical Discharge," *The London, Edinburgh, and Dublin Philosophical Magazine & Journal of Science*, Vol. 40, July 1870, pp. 42–51.
28. Aitken, *Syntony and Sparks*, p. 92.
29. Lodge, *PM*, Aug. 1888, pp. 217–230.
30. Lodge, *PRS*, 1891, p. 23.
31. John Bryant, "The First Century of Microwaves—1886–1986," *IEEE Trans. on Microwave Theory and Techniques*, Vol. 36, No. 5, May 1988, p. 831.
32. "Discussion," *Electrical Review*, Vol. 23, Sept. 21, 1888, p. 307: "Prof. Lodge said when the wavelength was 76 metres he was using pint sized jars; with 166 metres he used gallon jars. There was a very curious and a very important thing about the spark which was precipitated by what they called the primary spark." This effect was reported by Hertz in some of his early papers.
33. "Berlin," *Nature*, Vol. 37, Mar. 8, 1888, p. 456.
34. Lodge, "Measurement of Electromagnetic Wavelength," *Electrician*, Sept. 14, 1888, p. 608.
35. Lodge, *PRS*, June 4, 1891, p. 24.
36. A. Heydweiller, "The Determination of High Potential Differences," *Electrician*, Vol. 30, Apr. 12, 1893, p. 682; the author concludes that for small electrodes no spark gap distances over l cm should be used, but larger electrodes should be used for higher voltages.
37. Lodge, *JSA*, 1888, p. 889.
38. Lodge *PM*, p. 889.
39. Lodge, *Electrician*, Sept. 14, 1888, p. 608.
40. Milton Kiver, "Theory and Application of U.H.F.," *Radio News*, May 1944, pp. 50–52, 106.
41. Lodge, *PRS*, 1891, p. 28.
42. Lodge, *JSA*, 1888, p. 890.
43. Heinrich Hertz, *Annalen der Physik*, p. 445. May 15, 1887; translated in Heinrich Hertz, *Electric Waves,* (Macmillan and Co., London, 1893) p. 51. (In the MKS system, the dimensions are in meters and the resulting self-inductance is in nH.)
44. Oliver Lodge: "Discussion on Lightning Detectors," *JIEE*, Vol. 18, 1889-05-09, p. 477.
45. Voss Influence Machine, National Museum of American History, Catalog No. 315900, made

c. 1890, overall dimensions 17 in × 25 in × 13 in (43.18 cm × 63.5 cm × 33.02 cm).

46. Lodge, *Past Years*, p. 154.
47. The diameters of the rods in Lodge's Voss machine appear in: Oliver Lodge, "Lightning Conductors—VII," *Electrician*, Jan. 4, 1889, Vol. 22, p. 245.
48. Robert Plonsey and Robert Collins, *Principles and Applications of Electromagnetic Fields*, (McGraw Hill Book Co., New York, 1961) p. 280.
49. Lodge, *PRS*, 1891, pp. 33–34.
50. Lodge, *Advancing Science*, p. 111.
51. Lodge, *Lightning Conductors and Lightning Guards* (Whittaker & Co, London, 1892); Lodge made the following tentative assertions about the frequency content of lightning that he was attempting to simulate with the discharges of his Leyden jars: "The main point established is that for frequencies comparable to a million per second, such frequencies as occur in jar discharges and probably in lightning..." (p. 117); also, "A lightning discharge is essentially a varying current; it manifestly rises from zero to a maximum, and then dies away again, all in some extremely small fraction of a second, say 100,000th or thereabouts." (p. 38). A pulse that lasts for 10 μsec has much of it energy content at a frequency on the order of 100 kHz, which translates into wavelengths of 3 km.
52. Lodge, *JSA*, 1888, p. 890 fn.
53. Lodge, *PM*, p. 228.
54. Oliver Lodge, *Advancing Science*, p. 92.
55. "Standing Waves," Physics 51 Review/Lecture Notes, Duke University; https://webhome.phy.duke.edu/~rgb/Class/phy51/phy51/node34.html.
56. Lodge, *PM*, 1888, p. 229.
57. Lodge, *Past Years*, 1931.
58. Ibid., p. 230. While Lodge used the "æther" spelling in this quote, the more familiar "ether" spelling is used throughout the paper.
59. Bruce J. Hunt, *The Maxwellians*, (Cornell University Press, Ithaca and London, 1991) p. 157.
60. Russell Burns, "Communications: An International History of the Formative Years," (*IEE*, London, 2004) p. 270.
61. Lodge, *Modern Views of Electricity*, pp. 235–36.
62. David Baird, R.I.G Hughes, and Alfred Nordmann, eds., *Heinrich Hertz: Classical Physicist, Modern Philosopher*, (Kluwer Academic Publishers, Dordrecht, 1998) p. 74.
63. This is how the footnote appeared on page 609 in Vol. XXXIV, issue No. 8(a) of *Annalen der Physik*. Note that in Hertz's book *Electric Waves*, this footnote, which appears on the first page of Chapter VIII, reads: "See VII, p. 107, reproduced in Chapter VIII."
64. H. Hertz, Sitzungsber. d. Berlin Acad., 9 Feb. 1888, also reprinted in the previous issue of this Annalen. *Ann. d. Phys u. Chem*. N.F. XXXIV.
65. "Discussion," *Electrical Review*, Vol. 23, Sept. 21, 1888, p. 307.
66. Lodge, *Advancing Science*, (Ernest Benn Ltd., London, 1931) p. 92.
67. Lodge, *Past Years*, p. 185.
68. Oliver Lodge, *Lightning Conductors and Lightning Guards*, (Whittaker & Co, London, 1892) p. 106.
69. Lodge, *Past Years*, p. 227.
70. Oliver Lodge, "On the Measurement of the Length of Electro-magnetic Waves," *Report of the 58th Meeting of the British Association Held at Bath in September 1888,* (John Murray, London, 1889) p. 567.
71. J. G. O'Hara and W. Pricha, *Hertz and the Maxwellians*, *A Study and Documentation of the Discovery of Electromagnetic Radiation*, 1873–1894, (Peter Peregrinus Ltd., London, 1987) pp. 22–26.
72. Ibid.
73. FitzGerald, *Report of the 58th Meeting of the British Association*, p. 558.
74. Ibid.
75. Ibid.
76. Lodge, *Electrician*, Vol. 21, Sept. 14, 1888, p. 608.
77. FitzGerald, *Report of the 58th Meeting of the British Association*, p. 558.
78. Lodge, *Past Years*, p. 214.
79. Lodge, *Past Years*, p. 185.
80. Heaviside, "On the Extra Current," *Phil. Mag.*, 5th series, Vol. 2, Aug. 1876, pp. 135–145.
81. Reference for figure: S. M. Cvetićanin, D. Zorica, & M. R. Rapaić, "Generalized Time-fractional Telegrapher's Equation in Transmission Line Modeling," *Nonlinear Dynamics*, Vol. 88, 2017, pp. 1453–1472 (2017); https://doi.org/10.1007/s11071-016-3322-z.
82. Lodge, *PRS*, June 4, 1891, pp. 2–39.
83. Oliver Lodge, "Sketch of the Electrical Papers in Section A at the recent Bath Meeting of the British Association," *Electrician*, Vol. 21, Sept. 21, 1888, p. 623.
84. Lodge, *Electrician*, Vol. 21, Sept. 14, 1888, p. 608.

85. Lodge, *PRS*, 1891.
86. Ibid., p. 27.
87. Ibid.
88. Oliver Lodge, "Lightning Conductors–II," *Electrician*, Vol. 22, Nov. 9, 1888.
89. Ibid., p. 8.
90. Lodge, *JSA*, 1888, p. 890.
91. Ibid., Lodge wrote for the first time that he had subsequently determined the capacity of the gallon-sized Leyden jar to be 0.006 microfarad rather than 0.004 microfarad: "Now arrange a gallon Leyden jar (of capacity, as subsequently determined, 55 metres electrostatic units, or .006 microfarad)…"
92. Lodge, *PRS*, p. 27.
93. Ibid.
94. Lodge, *Electrician*, Vol. 21, Sept 14, 1888, p. 608.
95. Lodge, *JSA*, 1888, p. 890.
96. Lodge, *Electrician*, Vol. 23, Sept. 21, 1888, p. 306.
97. Lodge, *PRS*, 1891, p. 23.
98. "Physical Society," *Electrician*, Vol. 27, June 19, 1891, p. 200.
99. Lodge, *PRS*, 1891, p. 28.
100. Lodge, *Electrician*, Vol. 21, Sept. 21, 1888, p. 623.
101. Lodge, *PRS*, 1891, pp. 28–9.
102. Lodge, *Lightning Conductors and Lightning Guards*, pp. 108–109.
103. O'Hara & Pricha, p. 93.

About the Author

Eric Wenaas has had a life-long passion for electronic communication systems since childhood. He pursued this passion, first by collecting antique wireless and radio equipment, and later by attending Purdue University where he received BS and MS degrees in electrical engineering. He then received his Ph.D. in Interdisciplinary Studies in Engineering Sciences State University of New York (SUNY) in Buffalo.

After a lifetime career in studying electromagnetic effects on electronic systems for several defense contractor companies, he retired and began to research the early days of wireless to document interesting historical vignettes based on original documents of the era. He has written over forty articles for the *AWA Journal* and *AWA Review* on the history of wireless telegraphy, wireless telephony, and radio. He has also reviewed over 30 books for the AWA *Journal* and three books for the *IEEE Technology and Society Magazine*, all addressing the history of electronic communication. He finished serving a term of four years as the editor of the prestigious *AWA Review* in 2019, and he is now writing another book, this time on the history of early vacuum tubes made in America. During his career, he was a member of the IEEE and is currently a lifetime member and Fellow of the AWA, and a member of the Radio Club of America and several other radio organizations.

Eric Wenaas

Letter to the Editor

Re: The Centennial of KDKA's Historic 1920 Broadcast

Dear Mr. and Ms. Bart

Please let me introduce myself as a Fellow in AWA. I have been reading your nice article on "The Centennial of KDKA's Historic 1920 Broadcast," recently published in the *AWA Review* Volume 33. So, as a matter of cooperation, I am sending you enclosed hereto a file covering a brief article on DXing KDKA in Brazil back in early twenties [1920s], which I have published in the magazine *CQ*. ["DXing KDKA from Brazil, 1923-25," *CQ plus*, December 2014, pp. 127 to 130, by Carlos Alberto Fazano.] Considering they are related matters on such centennial broadcaster, I understand it might be of your interest.

If so, please feel free to use it as you want, bearing in mind kindly to acknowledge the *CQ* magazine. In the meantime, the article is already inserted in my website at www.fazano.pro.br in the bibliography section.

Thank you again for your kind attention and please be free to contact me anytime as you want.

Regards
Carlos Alberto Fazano, PU2KFZ

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Letter to the Editor

Re: Harvard's Radio Past: A Sort of Memoir: Continuation Part II

Dear AWA Review editor:

I sent a copy of the latest *AWA Review* (Vol. 33, 2020) to Prof. Gerald Holton of the Harvard Physics Dept. He is nearly 100 and was a student of Walter Cady at Wesleyan in the late 1930s. Here is the letter he just sent me.

David Wunsch

From: Gerald Holton
Date: Thursday, June 18, 2020 at 4:04 PM

Dear David Wunsch,

I received your thoughtful and generous gift of *The Antique Wireless Association Review*, Vol. 33. Because of its wide ranging and impressive scholarship on your part, your chapter will be an excellent addition to the Part I you kindly sent before. The frequent connection of your work with Harvard's history at that time makes your chapter very valuable in Harvard's present project to collect and make available to its students and researchers its beginnings as a serious department.

Therefore I am sending your book to Sara Schechner at the Harvard History of Science Department. As you may recall, she is in charge of the acquisition of historically valuable materials, and to her great pleasure we sent your Part I to her some time ago. Let me add that I greatly enjoyed your essay, not only for its scholarship, but also for letting it hint of your passionate pursuit of important details, great or small.

With best regards,
Gerald Holton